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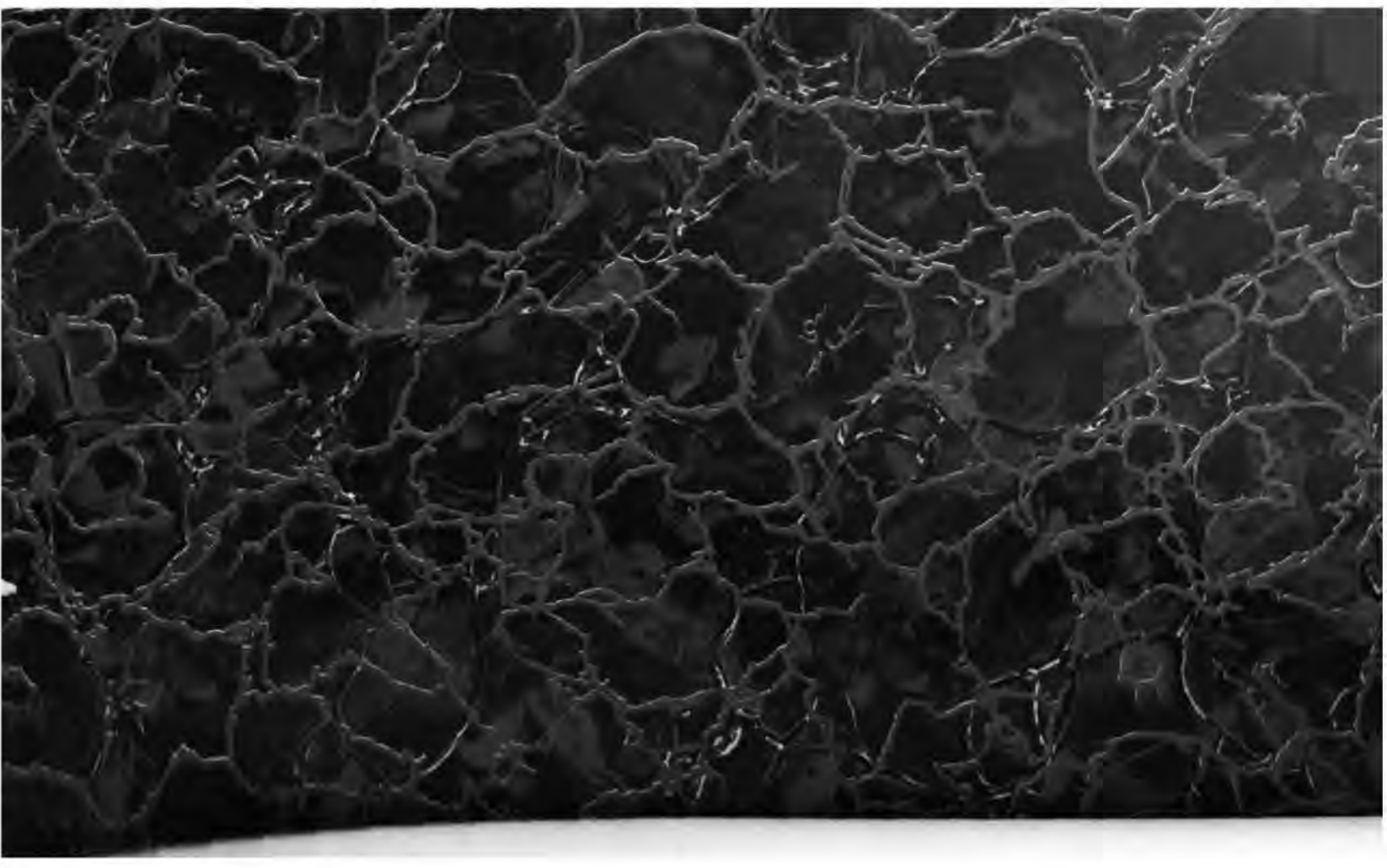

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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

NAUTICAL TERMS
MOTOR BOATS
MARINE GASOLINE ENGINES
MANAGEMENT OF MARINE GASOLINE ENGINES
MOTOR-BOAT NAVIGATION
MOTOR-BOAT RULES AND SIGNALS

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the

indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one to select the proper formula, method, or process and in teaching him how and when it should be used.

The subject of Motor Boats presented in this volume embraces all methods of practical utility in the operation, care, and management of motor craft. Special attention is given the various types of gasoline engines used on motor boats, the construction and manipulation of such engines being fully explained. In the Section on Electric Ignition detailed descriptions are given of all sources of current supply used on motor boats. The same careful attention is paid to the subjects of bearings and lubrication, gasoline supply, auxiliaries, and the prevention and detection of all kinds of motor troubles. Under the heading of Motor-Boat Navigation are explained all methods of coast navigation, including chart work, best suited for the navigation of power boats. It gives the student a correct and proper knowledge of the compass, the lead, and the log, and the handling and navigating of boats during fog and in heavy weather. The housing and caretaking of motor boats during winter and the work of placing them in commission at the opening of the season is explained. There is hardly any feature connected with motor-boat running which is not covered in this volume with a wealth of detail unsurpassed in clearness and real usefulness to the motor-boat operator.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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NAUTICAL TERMS

TERMS RELATING TO NAVIGATION AND SEAMANSHIP

WATER CRAFT

1. There are many terms and phrases employed by the nautical profession that should be understood by the yacht owner, the power-boat owner, and the men engaged in the operation of these craft. While not absolutely necessary to the motor-boat operator, a correct understanding of these terms will add much to the pleasure of boating, and at the same time will place him on the level occupied by the best-informed yachtsman.

As a rule, the terms vessel, boat, and ship are used indiscriminately by the public, and for this reason each will be briefly defined.

2. **Boat** in a broad sense, means any water craft; generally, it indicates a small open vessel or water craft moved by oars or paddles, but often by a sail or some power mechanism. Usually, the term boat is used in combination with some word descriptive of the use or mode of propulsion, such as rowboat, sailboat, motor boat, pilot boat, fishing boat, and so on.

3. By a **vessel** is meant a craft designed to float on the water, usually one larger than an ordinary rowboat, in fact any water craft constructed with a deck. This term may therefore be applied to any craft afloat larger than a rowboat. According to definition given by the Revised Statutes of the

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United States, the term vessel indicates every description of water craft or other artificial contrivance used, or capable of being used, as a means of transportation on the water.

4. The term **ship,** on the other hand, means a large sea-going vessel usually with three or more masts carrying sails. In general, it means a vessel of considerable size, and suitable for deep-water navigation. A ship whose motive power is steam is termed a **steamship** and sometimes **steamer.**

A ship or any large vessel is not properly designated a boat, which term should be used only when referring to open craft of small size, except when a special modifying word precedes the term, as in power boat, torpedo boat, towboat, etc.

TERMS INDICATING POSITION AND DIRECTION

5. To assist in the explanation of the principal terms relating to position and direction a representation of the deck plan of a vessel is shown in Fig. 1.

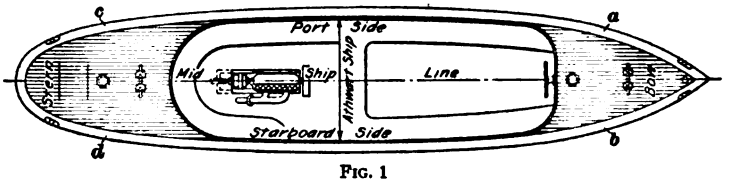


FIG. 1

The fore end of a boat or ship is designated as **bow.** The after part as **stern,** and the middle part, with regard to either length or breadth, is known as the **midship section** of the vessel. The foremost part of the bow that cleaves the water is known as the **stem.**

The **fore-and-aft line** of a vessel runs from bow to stern or vice versa; it is known also as the *longitudinal midship line.* This line coincides with the direction of the keel and divides the vessel in two equal parts known, respectively, as the **port** and **starboard sides,** port being to the left and starboard to the right of a person looking from the stern toward the bow.

The forward starboard side *b* is the *starboard bow;* the opposite side *a* is the *port bow.* Anything located toward the bows

is said to be *foreward*, and any object near the middle of the vessel's length is said to be *amidships;* anything located toward the stern is said to be *aft.*

The starboard side aft *d* is the *starboard quarter*, and the corresponding or opposite side *c* is known as the *port quarter.*

Athwarthship means across the length of a vessel, or a direction perpendicular to any point along the fore-and-aft, or midship line. **Abeam** and **abreast** designates a direction at right angles to the vessels fore-and-aft line; also opposite the center of the vessel.

6. Anything situated so that its direction is parallel to the midship line is said to lie *fore and aft;* if at right angles to this line it is said to have an athwartship direction. In speaking of the position of any part relatively to another part the terms *before* and *abaft* are used in the sense of forward of and aft of, respectively.

The direction from either side of the vessel toward the midship line is known as *inboard*, the reverse direction as *outboard. Overboard* is into the water from over the vessel's sides.

Viewed from the vessel, an object in front of it is said to be *ahead;* one behind it is *astern;* while one opposite the middle part of the vessel is *abeam* or *abreast.* Again, the vessel is said to be abeam or abreast to any object fixed or floating. External objects lying between ahead and abeam are said to be *on the bow*, port, or starboard, as the case may be, while objects sighted between abeam and astern are said to be *on the quarter.*

Dead ahead is a direction exactly perpendicular to the vessel's athwartship line. When an object is sighted dead ahead its bearing or direction from the vessel coincides with the direction of the keel or the fore-and-aft line. **Dead astern** is the opposite of dead ahead. When a vessel moves forward she is said to be *going ahead;* when moving in the opposite direction she is *backing* or *going astern.*

Aloft refers to any part of a ship situated above the hull, particularly the higher, or loftiest, part of the rigging. *Going aloft* means going up in the rigging of a ship.

7. Compass Directions.—The apparent boundary between the sky and the sea, or between the sky and the land, that appears to be encircling an observer having an uninterrupted view, is known as the *horizon*. To designate the direction from the observer to any particular point on the horizon, or any point situated between the observer and the horizon, **compass directions** are generally used.

The principal compass directions are north, south, east, and west, as shown in Fig. 2, where *o* represents the position of an observer. North and south, east and west are diametrically opposite directions, as indicated by the arrowheads, and the spaces between the principal, or *cardinal points*, as they are often called, are divided into eight equal parts, making the whole circumference of the horizon to be divided into thirty-two points. The circumference bounding the horizon is divided also into 360° so that any direction may be expressed either in points or in degrees. Thus, the direction of the point *x* from *o* is north 4 points east or north 45° east, whichever expression may suit the purpose best.

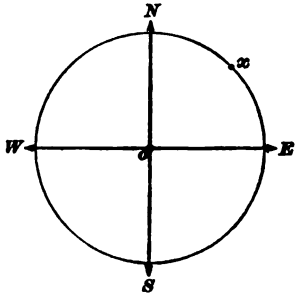


FIG. 2

8. Name of Compass Points.—Each of the thirty-two compass points has a name and the process of repeating these names, as they occur on a compass card, in regular sequence from north around by way of east or west and back to north, also naming the points diametrically opposite any given point, is commonly known as *boxing the compass*. The method of naming the compass points is readily understood by reference to Fig. 3. Commencing from the north point at the top of the card and going around to the right, or in the direction in which the hands of a watch move, the names of the points are as follows: *NORTH*, *north-by-east*, *north-northeast*, *north-east-by-north*, *northeast*, *northeast-by-east*, *east-northeast*, *east-by-north*; *EAST*, *east-by-south*, *east-southeast*, *southeast-by-east*, *southeast*,

southeast-by-south, south-southeast, south-by-east; SOUTH, south-by-west, south-southwest, southwest-by-south, south-west, south-west-by-west, west-southwest, west-by-south; WEST, west-by-north, west-northwest, northwest-by-west, northwest, northwest-by-north, north-northwest, north-by-west, NORTH.

9. The name of the opposite point to any given point is known simply by reversing the names or the letters that indicate the given point. Thus, the opposite point of N E by E is S W by W, that of E by S is W by N, and so on. As stated before, the compass card is divided also in degrees commencing

FIG. 3

with 0 at the north point and terminating with 360° at the same point, as shown in Fig. 3. Thus, east is 90°, south 180°, and west 270°. The compass and its use will be fully explained later.

10. By **course** is understood the particular direction in which a vessel is being run or steered at any given time. Technically expressed, it is the angle that the vessel's fore-and-aft line makes with the north-and-south lines of a compass card. For this reason, the course is measured either in degrees or in points. Thus, if a vessel is steering midway between north

and west her course is northwest, N 45° W, or, according to the latest way of reading the compass card, 315°.

11. The **bearing** of an object is the direction of that object from the observer. Like the course, it is measured in points or degrees and consequently is expressed as an angle that the line of bearing makes with the north-and-south line of a compass card. Thus, the line *a o*, Fig. 4, is the bearing of the

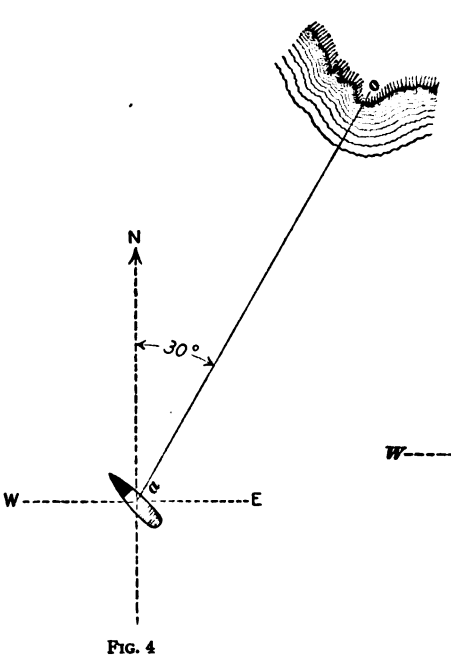


FIG. 4

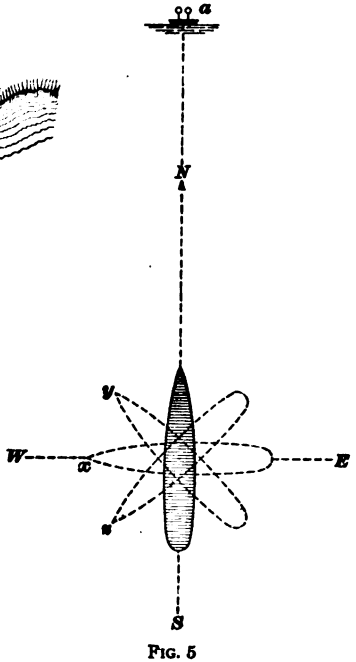


FIG. 5

point *o* from the vessel at *a*, and if the dotted lines represent compass direction the bearing of *o* is about N 30° E, as shown. From the figure it is evident that the line of bearing to a point is identical to the course to that point. In other words, to reach *o* the vessel at *a* must steer a course N 30° E.

12. The **distance** between two places, or the distance run by a vessel on any course, is the length of the line of bearing between the two places considered. If the distance is con-

siderable, it is usually expressed in miles, nautical or statute; if short, it may be expressed or measured in yards. A statute, or land, mile is equal to 5,280 feet while the nautical, or sea, mile is 6,080 feet long. The latter is the mean value of 1 minute of latitude, or $\frac{1}{60}$ of one degree of latitude. Distances run at sea are usually measured in nautical miles, or *knots*. A knot is a speed of one nautical mile per hour. Thus, a vessel running 15 nautical miles per hour has a speed of 15 knots.

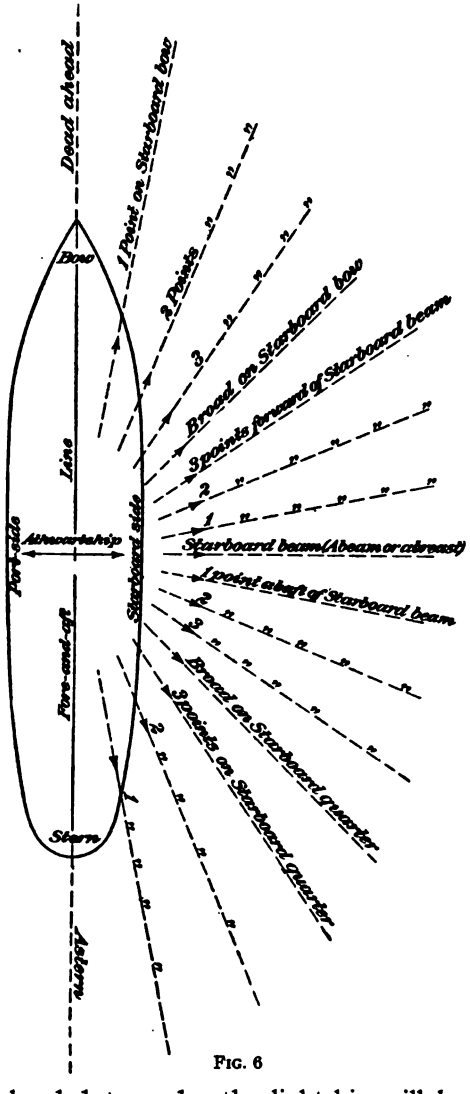


FIG. 6

13. Relative bearings are bearings that refer exclusively to the direction in which a vessel is heading. Thus, in Fig. 5, if a vessel is headed north and the lightship *a* is sighted dead ahead the same lightship will be abeam if the vessel is headed east or west as at *x*. If headed in the direction of *y*, the lightship will be on her starboard bow, and if headed toward *z* the lightship will be on the starboard quarter.

14. Relative bearings are usually names in points; beginning from dead ahead on the starboard side, as shown in Fig. 6, they are:

Ahead
1 point on starboard bow
2 points on starboard bow
3 points on starboard bow
Broad on (or off) starboard bow
3 points forward of starboard beam
2 points forward of starboard beam
1 point forward of starboard beam
Starboard beam (abeam or abreast)
1 point abaft starboard beam
2 points abaft starboard beam
3 points abaft starboard beam
Broad on (or off) starboard quarter
3 points on (or off) starboard quarter
2 points on (or off) starboard quarter
1 point on (or off) starboard quarter
Astern

From ahead to abeam is eight points, from ahead to astern is sixteen points, from broad off bow to broad on quarter is eight points, and so on. The bearings on the port side are designated in a similar manner, the word starboard in each case being replaced by port.

15. Windward and Leeward.—Wind is named according to the direction from which it comes. Thus, the wind blowing from the north is a northerly wind; and from the east, an easterly wind. **Windward** is the direction from which the wind blows and **leeward** is the direction toward which the wind blows. A wind blowing practically against the ship's course is a *head wind;* a wind from abaft is a *following wind.* Wind is designated also as being on the beam, on the quarter, and on the bow, as the case may be.

16. Working to Windward.—When a sailing vessel, by reason of a head wind, cannot steer directly for her destination, her head is laid as close to the wind as her sails will

permit. The vessel is then said to be *close hauled* on either port or starboard *tack*, depending on which side of the ship is facing the wind. When the wind is on the starboard side, the vessel is on the *starboard tack;* when on the port side, it is on the *port tack*. Thus, in Fig. 7, the ships *a* and *c* are both on the port tack, while *b* and *d* are on the starboard tack, the arrows indicating the direction of the wind. A ship heading alternately on port and starboard tacks, trying to reach her destination by a zigzag course in the face of a head-wind, as shown in the figures, is said to be *beating to windward*, or *working to windward*. Few vessels can lie closer than five points to the wind. A square-rigged vessel usually cannot get closer than six points, as indicated in the figure.

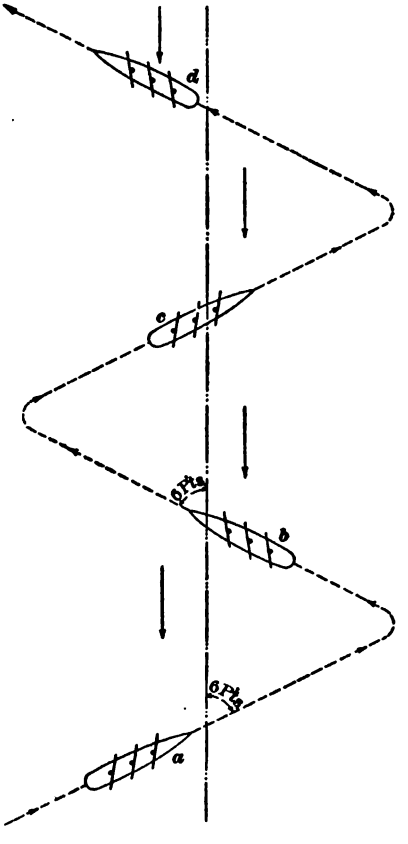


FIG. 7

17. Adrift means floating at random without control. Thus, a boat or vessel is said to be adrift or drifting when broken from her moorings, or when her machinery or sails cannot be used to control her progress in any desired direction.

18. Aground indicates the situation of a boat or any floating vessel, log, or raft that is in direct contact with, or resting on the ground. It also signifies stranded or the state of being disabled or hindered by having run ashore.

19. **Sternboard** is a term indicating the backward motion of a vessel. A sailing vessel is said to be *gathering sternway*, or sternboard, when, by misadventure, or purposely, her head is brought up against the wind with her sails aback, causing her to drift backwards.

20. **Lie-To.**—When a vessel encounters a strong gale and her head is laid as close to the wind as possible, in order to prevent seas from boarding her, she is said to **lie-to** or **heave-to.** Also, when a vessel stops at sea or off a port without anchoring, she is said to lie-to or to be heave-to.

21. **Under Way.**—A vessel is said to be **under way** when she is moving through water in any desired direction; or, in general, when she is not at anchor, or made fast to the shore, or aground.

22. **Under weigh** applies, in particular, to the operation of preparing a vessel to get under way, such as unfurling the sails or getting up steam and weighing the anchor.

23. By the **wake** of a ship is understood the glossy and sometimes smooth track left on the surface of the water behind an advancing ship.

24. By **dead water** is understood the eddy water under and about the stern of a vessel when under way. It is so called because it passes away slower than the water alongside the vessel.

25. To **hug** the shore is to run as close to land as is consistent with safety. When a sail boat hugs the shore the wind as a rule blows from the shore; in other words, the shore is to windward.

26. **Rolling and Pitching.**—When a vessel from some cause, as having the sea on her beam, rocks from side to side she is said to **roll**; when her bow and stern rise and fall alternately, she is said to **pitch.** It is evident that a vessel can roll and pitch at the same time under certain conditions of the sea and wind.

27. Heeling.—When a boat or vessel is resting on the water in an upright position with her deck or seats parallel to the surface of the sea, she is said to be on an *even keel;* but, when canted to one side or other, intentionally or not, she is **heeling,** or **listed,** to that side. Thus, a vessel inclined to one side is said to have a list to port or starboard as the case may be.

TERMS RELATING TO DISPLACEMENT AND TONNAGE

28. Displacement.—In the technical sense in which the term **displacement** is applied to ships or any other floating bodies it refers to the displacement of the water by the total or partial immersion of an object placed in it. When any body is immersed in water, it displaces a quantity of water equal in volume to its own bulk. If the weight of the displaced water is greater than the weight of the immersed body, the latter will float. For example, if a block of wood 1 cubic foot in volume and weighing 48 pounds is placed in sea-water, and since 1 cubic foot of sea-water weighs, on the average, 64 pounds, it is evident the amount of water displaced will be $48 \div 64 = \frac{3}{4}$ cubic foot and consequently one-fourth of the block will be above water. Likewise, a cast-iron box with sides $\frac{1}{4}$ inch thick and measuring 12 inches either way inside will have about the same weight as the block of wood and will displace the same amount of water.

29. From the foregoing, several terms associated with displacement may be readily explained. Thus, imagine a model of a boat, Fig. 8 (*a*), to be made in the form of a box 12 feet long, 3 feet wide, and 2 feet deep, its total weight being 1,152 pounds. If the box is floated in salt water, the displaced water has a volume of $1{,}152 \div 64 = 18$ cubic feet. And as the area of the bottom of the box is $12 \times 3 = 36$ square feet it is evident that the box sinks to the extent of $18 \div 36 = .5$ foot, or 6 inches, before the weight of water displaced balances the weight of the box. This is equivalent to saying that the box draws 6 inches of water when light or unloaded.

To float the box so as to have an immersion, or draft of 16 inches, it is necessary that an additional displacement of $12 \times 3 \times 1\frac{9}{2} = 30$ cubic feet, equal to a weight of $30 \times 64 = 1{,}920$ pounds, be put in the box, as shown in (*b*). The total weight of box and cargo will then equal $1{,}152 + 1{,}920 = 3{,}072$ pounds, which exactly balances the amount of water displaced.

30. Dead Weight.—From the foregoing it is evident that the weight of the water displaced by the ship corresponds to the displacement; but the weight of the cargo placed on board is known as the **dead weight.** Thus, in the box shown in Fig. 8 (*b*) the load of 1,920 pounds is the dead-weight capacity

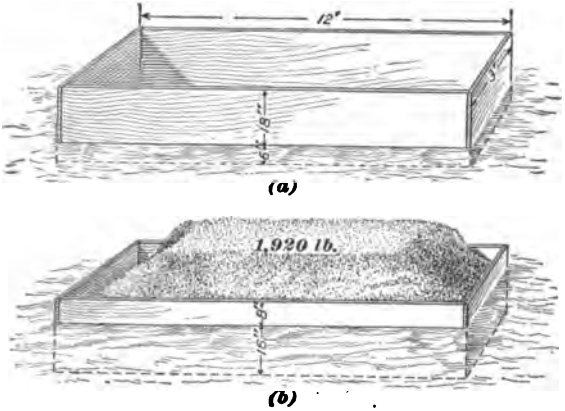


FIG. 8

of the box or the weight necessary to bring it to a loaded draft of 16 inches. The 8 inches of the sides of the box remaining above the water is known as the **freeboard,** and the line separating the freeboard from the wetted surface of the box is called the **water-line.**

31. Tonnage.—The term tonnage refers to the internal capacity or volume of a vessel. A tonnage certificate or a register of shipping shows two distinct classes of tonnage; namely, *gross* and *net tonnage.* The former is the entire internal capacity measured according to certain rules, as specified in the navigation laws of the United States, and according to

the size and the type of vessel. Net tonnage is the remainder after having taken from the gross tonnage allowances for crew space, engine and boiler room, shaft alley, and so on. It is supposed to represent the earning capacity of the ship and is therefore made the basis for port and navigation charges.

32. The displacement, or gross tonnage, may be approximately estimated by multiplying the product of length, beam, and draft by .6 and then dividing by 35. Thus, if a vessel is 40 feet long, has a 10-foot beam, and draws 5 feet of water, her displacement will be, approximately, $\frac{40 \times 10 \times 5 \times .6}{35} = 34.3$ tons. By deducting from this the crew and engine space, the net tonnage is obtained. For detailed information for finding the displacement from the plans of a power boat good works on motor-boat construction and design should be consulted.

33. Displacement and tonnage are often spoken of by the layman as being one and the same thing. This, however, is incorrect. Displacement, as already stated, is the weight of water displaced by the ship, or the total weight of the ship itself with everything on board. Hence, the displacement of a vessel may vary from day to day or from one voyage to another, according to cargo, coal, stores, etc. on board. Tonnage, on the other hand, being determined by the type and the internal dimensions of a vessel, remains constant.

TIME AND WATCHES ON SHIPBOARD

34. Watches.—For the purpose of securing a fair division of work among the crew of every seagoing vessel, the day on shipboard is divided into two divisions known as **watches,** the *port* and the *starboard watch.* Each watch is on duty 4 hours at the time, except the period from 4 to 8 P. M., which is divided into two watches of 2 hours each, called the *dog watches.* The object of this is to make an odd number of watches during the 24 hours, so that the starboard and port watches of the crew will not be on duty at the same time every day. The watches are designated as follows:

12 noon to 4 P. M.	Afternoon watch
4 to 6 P. M.	First dog watch
6 to 8 P. M.	Second dog watch
8 P. M. to midnight	First watch
Midnight to 4 A. M.	Mid watch
4 to 8 A. M.	Morning watch
8 A. M. to 12, noon	Forenoon watch

By reason of the dog watches, which create an odd number of watches in the 24 hours, the members of the port and starboard watches are enabled to keep the other watches alternately on consecutive days, as the watch that is on duty in the forenoon one day has the afternoon duty the next day, while the men who have only 4 hours rest one night have 8 hours rest the next night.

35. **Time.**—The time on shipboard is marked by strokes on the ship's bell, and is expressed by the number of bells (strokes) that have been struck; thus, 1 bell is one stroke of the bell, 6 bells is six strokes of the bell, and so on. Counting from 12 o'clock, noon, which is 8 bells, the half hours through the day and night run as follows:

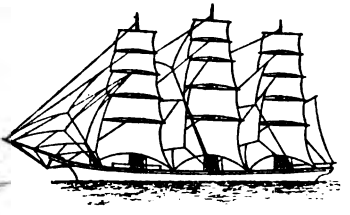
12:30 P. M.	1 bell	7:00 P. M.	6 bells
1:00 P. M.	2 bells	7:30 P. M.	7 bells
1:30 P. M.	3 bells	8:00 P. M.	8 bells
2:00 P. M.	4 bells	8:30 P. M.	1 bell
2:30 P. M.	5 bells	9:00 P. M.	2 bells
3:00 P. M.	6 bells	9:30 P. M.	3 bells
3:30 P. M.	7 bells	10:00 P. M.	4 bells
4:00 P. M.	8 bells	10:30 P. M.	5 bells
4:30 P. M.	1 bell	11:00 P. M.	6 bells
5:00 P. M.	2 bells	11:30 P. M.	7 bells
5:30 P. M.	3 bells	12:00 midnight	8 bells
6:00 P. M.	4 bells	12:30 A. M.	1 bell
6:30 P. M.	5 bells	And so on as before	

TERMS RELATING TO VESSELS

MERCHANT VESSELS

36. Type of Rigging.—Vessels using wind as their motive power may be divided in two general classes; namely, fore-and-aft rigged and square-rigged vessels. *Fore-and-aft rigged ves-*

Four Masted Barque



Ship

Brig

Brigantine

Barque

Barkentine

FIG. 9 (*a*)

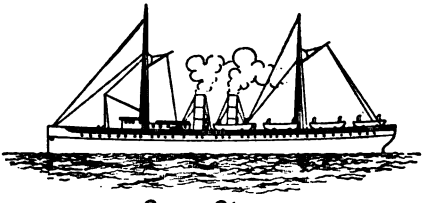
sels are those that carry only fore-and-aft sails, such as jibs, staysails, spankers, and trysails. *Square-rigged vessels* carry square or rectangular sails on one or more masts, in addition

to fore-and-aft sails. The former can sail closer to the wind than the latter. Steamers may be rigged the same as sailing ships. At the present time, however, the masts of a steamer are used principally as a support for booms and derricks, instead of sails. In Fig. 9 (*a*) and (*b*) are shown the principal types of rigging carried by sailing vessels.

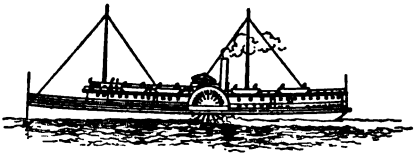
Schooner

Topsail Schooner

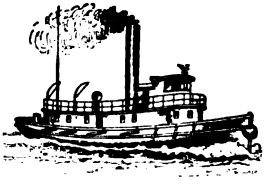
Yacht



Screw Steamer



Sidewheel Steamer



Steam Tugboat

FIG. 9 (*b*)

37. A **ship** is a vessel having square sails on at least three masts. The first mast is called the *foremast*, the second the *mainmast*, and the third the *mizzenmast;* if equipped with four masts, the fourth one is known as the *jigger mast.*

A **brig** has two masts, both of which carry square sails.

A **bark,** or **barque,** has three masts, two of which carry square sails, and the third a spanker and a gaff topsail.

The **barkentine** has three masts, but carries square sails only on the foremast, the second and third mast being equipped with fore-and-aft sails, as shown.

The **brigantine** has two masts, the foremast being equipped with square sails.

The **schooner** may have from two to five or even seven masts, all carrying fore-and-aft sails. They are extremely handy vessels, are well adapted for beating to windward, and for this reason are used exclusively in coastwise navigation. A *topsail schooner* has two masts, both of which carry fore-and-aft sails, the foremast in addition being fitted with square topsails. The masts in a fore-aft-schooner having more than 3 masts are usually designated by numbers, according to order, from the main mast; thus, fore, main, No. 3, No. 4, No. 5, No. 6, and so on.

NAVAL VESSELS

38. Battle ships are ships of large size, carrying the heaviest guns and thickest armor. They are designed to fight the most powerful ships of an enemy, but not, as a rule, to go far from a base. Such vessels carry their heavy guns in *turrets*. The characteristics of a battle ship are great size, moderate speed, heavy armor and heavy guns; its distinguishing features are broad beam, low freeboard, general massive appearance, and large turrets fore and aft.

39. Armored cruisers are ships of large size carrying guns and armor lighter than those of a battle ship, but heavier than those carried by any other class of ship (except monitors). They have greater speed than battle ships, and carry sufficient coal for steaming long distances and operating far from the base. The principal characteristics of an armored cruiser are very fine lines, great speed, great coal capacity, moderate guns, and moderate armor. In appearance, they differ from a battle ship by having high freeboard, less beam, lighter guns, and smaller turrets.

40. Protected cruisers are ships of moderate size with no side armor, but having their vital parts (engines, boilers,

and magazines) protected by a curved deck of steel from 2 to 4 inches thick. They have good speed and large coal supply, with guns of moderate power, and are designed for cruising on distant stations in time of peace and for blockading, scouting, and commerce destroying in time of war. As a rule, protected cruisers do not carry turrets but have their guns behind shields.

41. Gunboats are ships of moderate and small size, without armor or armored deck, with moderate speed and light guns, but often with very large coal supply. They are designed for cruising in time of peace and for blockading and commerce destroying in time of war; also for fighting against simliar ships of an enemy. They are often fitted with masts and sails.

42. Torpedo boats are light, low craft, very long and narrow. They are armed with torpedoes, and in some cases with a few light guns; they are designed to attack larger ships with torpedoes, usually under cover of darkness. Torpedo boats are, as a rule, small vessels, their displacements varying from about 25 to 250 tons, and are fitted with powerful engines to drive them at the required high speed.

43. Destroyers are large seagoing torpedo boats armed with torpedo tubes and guns of fair size. Their role is to accompany larger ships and protect them from torpedo boats, to attack the enemy's larger ships, and to run down and sink the enemy's torpedo boats and destroyers.

44. Submarines are small vessels of peculiar appearance capable of running on the surface of the water and also running submerged at any desired depth and thus, unseen, attack a hostile ship by the discharge of a torpedo. A **submersible** is distinguished from the submarine in that it is essentially a surface boat and dives only for attack or for concealment. It usually has two sources of motive power; one is a steam or gas engine for surface running, the other an electric motor with accumulators for running when submerged.

45. Man-of-War Boats.—*Launches* carried by warships are large heavy boats designed primarily for carrying cargo,

for laying out heavy anchors, or for transporting large bodies of men in landing operations. Their motive power is either steam or gasoline.

Cutters are like launches, but much smaller, and are used for both cargo and passengers; both launches and cutters are fitted

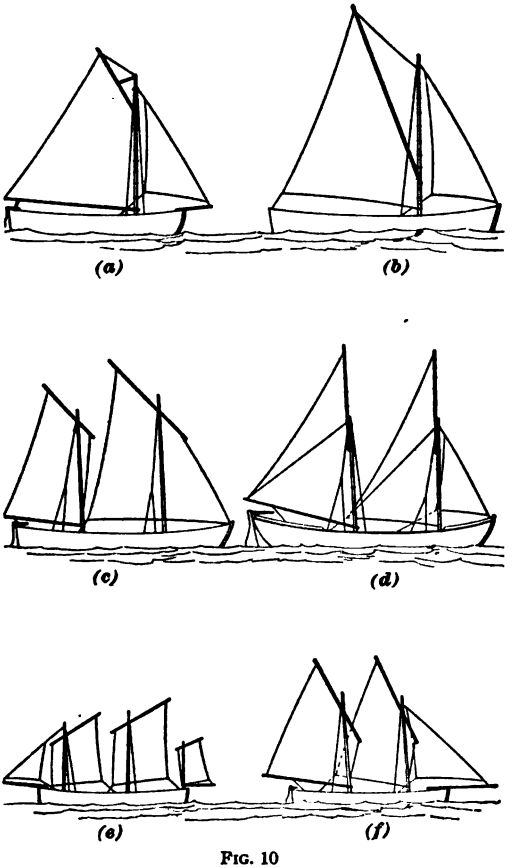


FIG. 10

for carrying light field guns. These boats are generally the life boats of the ship when under way.

Whale boats are lighter than cutters and of a different model, being sharp at the stern as well as at the bow; they are used for miscellaneous work, being light and handy.

Dingies are small boats, pulling usually four oars, used for light work of any kind.

The *barge*, used only in a flagship, is the personal boat of an admiral.

The *gig* is the personal boat of the captain; it is usually a small whaleboat.

Steam launches and *steam cutters* are boats of fair size run by steam and used for the general work of the ship.

In Fig. 10 are shown the various rigs of man-of-war boats for sailing, of which (*a*) is the gaff and boom rig used on launches of the United States Navy; (*b*) is known as sprit rig; (*c*) dipping lug foresail and standing lug mainsail; (*d*) sliding gunter; (*e*) balance lug; and (*f*) standing lug.

46. Terms Relating to Rowboats.—*Boats* are *single-* or *double-banked*, according as they have one or two oarsmen to a thwart.

Thwarts are the seats on which the crew sits; the space abaft the after thwart is called the *sternsheet*.

Floorings and *gratings* are the bottom boards of a boat; they prevent the weight from bearing directly upon the planking.

The *gunwale* of a boat is the upper rail.

The *yoke* is an athwartship piece of wood or metal fitting over the rudderhead. *Yoke lanyards* are the small lines made fast to the ends of the yoke, by which the rudder is turned and the boat steered.

The *stem* is the upturned portion of the keel at the bow of the boat, to which the forward ends of the planks are secured.

Oars are said to be *double-banked* when two men pull one oar. The *blade* of an oar is the broad flattened part. The *handle* is the small part of an oar on the inboard end of the loom, which the oarsman grasps when pulling. The *loom* is the portion of an oar extending from the blade to the handle. The *leather* is the portion of an oar that rests on the rowlock; this is sometimes covered with canvas, but is usually covered with leather, hence the name.

Feathering is the term applied to the operation of turning the blades nearly flat to the water after the stroke, with the

upper edge turned forwards, especially valuable in rowing against a head-wind.

Rowlocks are forked pieces of metal in which the leather of the oars rests while pulling. Swivel rowlocks are movable, a pin on the rowlock fitting into a socket in the gunwale.

Thole pins are wooden pins set vertically in the gunwale and are used in place of rowlocks.

The *steering rowlock* is a peculiar form of swivel rowlock, fitted near the stern of the boat, in which the steering oar is shipped; this is sometimes called a *crutch*.

The *painter* is a rope secured in the bow for towing or securing the boat.

Boat falls are tackles made with two blocks and a length of rope; used for hoisting boats.

The *plug* is the wooden stopper fitted into a hole in the bottom of a boat to let water in or out.

A *boat breaker* is a small keg used for carrying fresh water in a boat.

MOTOR CRAFT

47. Open Motor Boat.—In general, the term **open motor boat** denotes any motor boat without a cabin or accommodations other than seats in the cockpit, no particular form of hull being specified. If the speed is moderate and the beam is large in proportion to the length, an open boat is sometimes called a *family boat*.

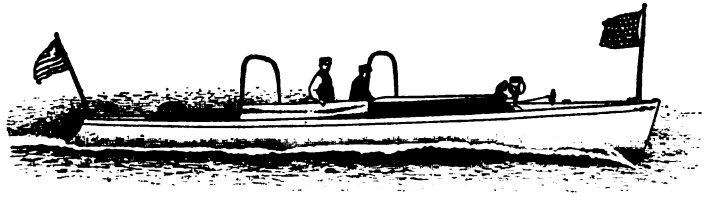


FIG. 11

48. A **semi-speed boat** is an open boat of the displacement type shown in Fig. 11. Its length is under 60 feet, generally about 25 to 30 feet, and comfort, passenger-carrying capacity, seaworthiness, strength, and safety are as essential

considerations as speed. If the motor is installed forward under a hood, with all controls brought to a bulkhead at the after end of the motor, this type is often called a *runabout.*

49. In **high-speed boats** every consideration is sacrificed to attain the highest possible speed. Some consideration, however, must be given to strength and seaworthiness, but none to the comfort of the crew or operator. These boats may be of either the hydroplane or the displacement type.

50. A **house boat** is a shallow, barge-like hull carrying a house, which affords comfortable living quarters. Large rectangular windows are used instead of port holes, as shown in Fig. 12. The draft is small, and when fitted with motors the

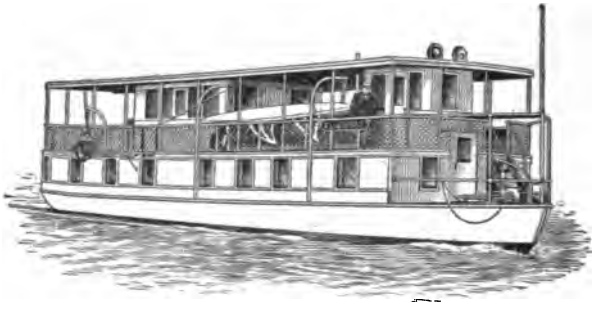


FIG. 12

speed is necessarily slow. Speed, seaworthiness, and general shipshape appearance are sacrificed for comfortable and roomy living accommodations.

51. In general, a **cabin boat** is any boat having a cabin for the accommodation of crew and passengers. A great variety of boats of this class are in commission at the present time for different purposes, both commercial and for pleasure. Many are most luxuriant in their appointments, being equipped and furnished to meet the individual ideas of their owners.

52. A **midship-deck cruiser,** generally, is a vessel 40 feet or more in length having an amidship bridge deck where all controls are located and where ample space is provided for the

helmsman to operate the steering gear. The midship deck extends the full width of the hull and the motor is generally located under this deck. An illustration of this type is shown in Fig. 13.

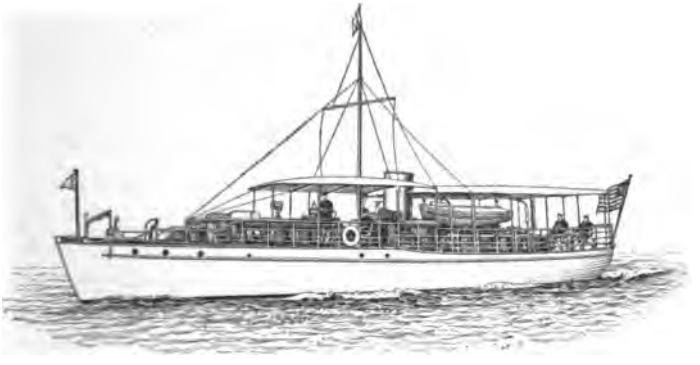


FIG. 13

53. In the **raised-deck cruiser,** the forward portion of the hull is carried up flush, so that headroom in cabin can be had under the deck without a house or trunk being fitted. The

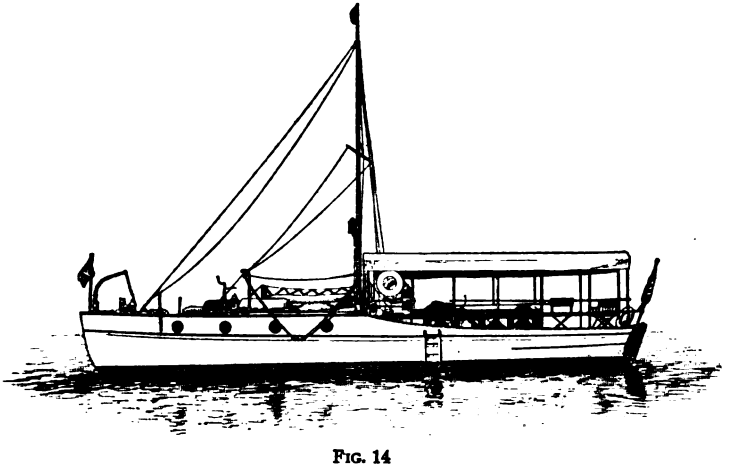


FIG. 14

portion of the hull thus raised usually extends to midship or farther, when it is gradually dropped to the lower sheer line. In the larger boats of this type, deck houses may be placed

in the after part, as shown in Fig. 14; while in the smaller boats, this part remains as an open cockpit with seating accommodations.

54. In the **flush-deck cruiser** all the cabins, staterooms, etc. are below the deck, sometimes having a deck house

FIG. 15

for the accommodation of the pilot. The advantage of this type, shown in Fig. 15, is a commodious deck space with an unobstructed all-around view of the horizon.

55. The **motor dory** is a development of the small boat used by the Banks fishermen. Originally having a narrow flat bottom and flaring straight sides, it has been so modified that in many cases the only remaining characteristic of the original model is the narrow, deep, raking, triangular transom. Dories equipped with motors are being used quite extensively as tenders to torpedo-boat destroyers in the United States Navy.

FIG. 16

56. **Tender** is the name given to boats carried on cruisers and yachts for taking parties and supplies to and from the landing place while the larger vessel is at anchor. Tenders may

or may not be fitted with motors. Large motor yachts sometimes carry racing tenders as well as substantially built and seaworthy ones. A representative type of a power and yacht tender is shown in Fig. 16.

57. A power canoe is a canoe in which a small motor is installed. In this type the canoe form is usually followed, although some later models are like the regulation speed boat, retaining only the light canoe construction.

58. Hydroplanes are lightly built racing boats of great power for their weight and so designed that they skim over the surface of the water when at speed, as shown in Fig. 17, instead of cutting through it. There are many forms of hydro-

FIG. 17

planes, some having steps or notches across the bottom, while others have a simple, smooth, flat, underbody. The latter class is known as the *monoplane.*

59. Of **life boats,** there are two classes, the first being carried by large vessels for the purpose of saving the crew and passengers in case of accident to the vessel; in the second class are the boats used at the life-saving stations along the coast to rescue the crew and passengers from ships wrecked on the shore. Life boats of the first class are usually propelled by oars, while those of the second class are operated with motors in addition to an auxiliary rig of sail, as shown in Fig. 18. They are so designed as to right themselves automatically if overturned by a heavy surf.

60. Commercial Motor Craft.—Though largely used on pleasure craft, the gasoline motor is more extensively adopted

as the motive power for commercial boats. Especially is this the case among fishermen, not less than 75,000 motor boats being used at the present time by persons engaged in the fishing, oyster, and lobster industry. In fact, on small and medium-sized craft, in general, the sail and the steam engine is being replaced by the gasoline motor owing to its peculiar and advantageous adaptability for various commercial requirements. In Figs. 19 and 20 are shown a few of the many types of commer-

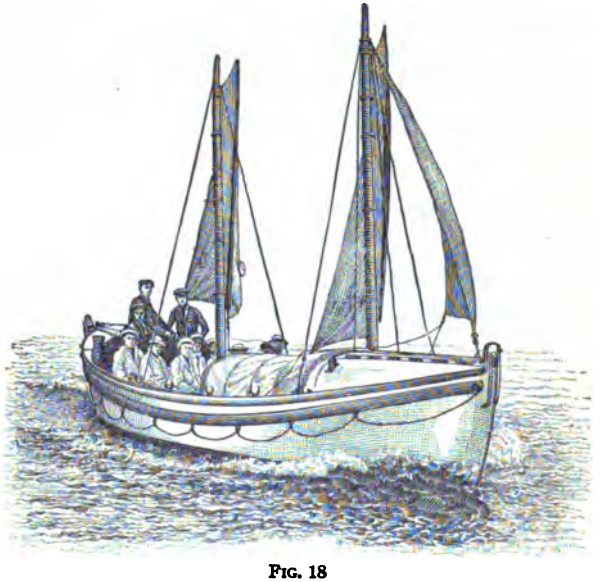


FIG. 18

cial motor craft in operation at the present time. In Fig. 20 (*a*) is shown a motor fishing boat; in (*b*), a salmon seine motor boat; in (*c*), a motor oyster boat; and in (*d*), a motor railway-car ferry. These craft are easily distinguished by the absence of funnels or smokestacks.

61. The proportion of power boats used for various commercial purposes to those used for pleasure appears greater on the Pacific Coast than in the East, possibly because the gasoline engine is admirably adapted to pioneering, no license being

required to operate it. On Puget Sound gasoline is displacing both sail and steam in business. In the halibut fishery it is employed for auxiliary power on sailing vessels. Gasoline

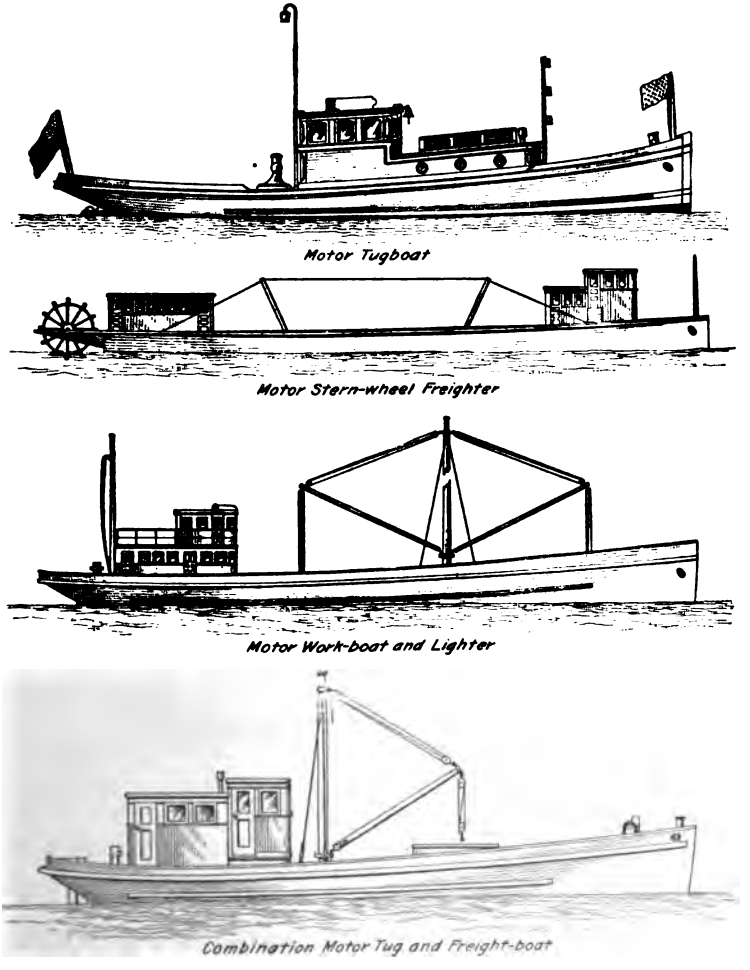
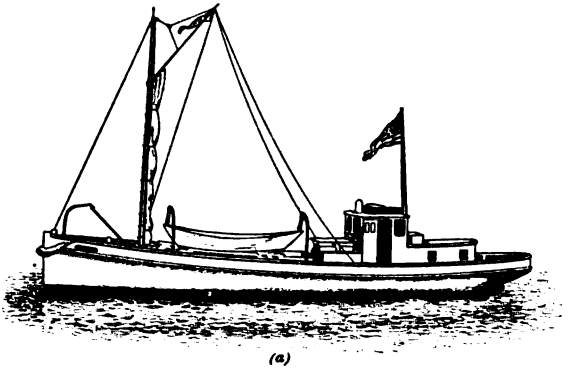


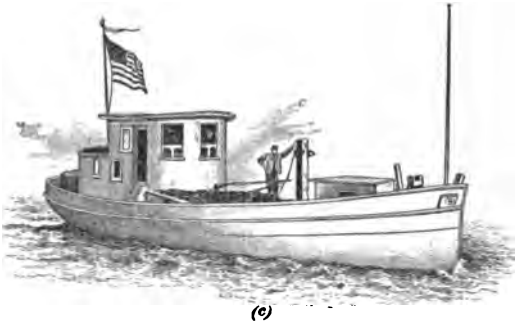
FIG. 19

tugs are also coming in. Gasoline freight boats are common, and here and there one sees a gasoline packet boat carrying passengers. Greater numbers of gasoline boats are used in



(a)

(b)



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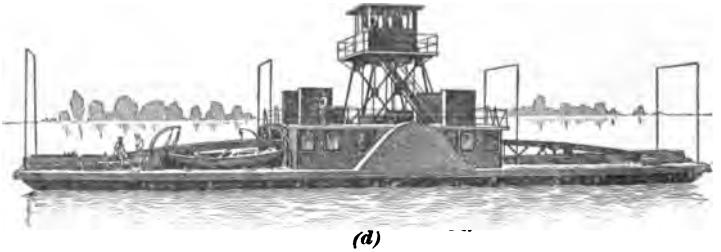


(d)

FIG. 20

the fisheries on the Atlantic than in any other commercial pursuit, though the small gasoline freight boat is rapidly appearing.

NOTE.—A more detailed discussion of the different types of motor boats classified according to their construction, deck arrangement, and use is given later.

ROPE AND LIGHT CORDAGE

KINDS OF ROPE

62. Manila rope is a cordage made from the fibers of wild banana, the entire supply of which comes from the Philippine Islands. This fiber is very strong and durable and is well adapted for the manufacture of small cordage. When dry, it contains 12 per cent. moisture and will absorb as much as 40 per cent. in damp atmosphere.

63. Hemp rope is made from the fibers of the hemp plant. The best hemp cordage is that manufactured from hemp grown in Russia. This rope is more flexible than manila but less strong and less durable. It decays rapidly if kept wet. Hemp rope is usually tarred, but when not tarred it is known as *white rope*. Tarring prolongs the durability of the rope but reduces its strength and flexibility. Manila ropes are never tarred.

64. Coir Rope.—The fiber of the outer husk of the cocoanut, known as *coir*, is occasionally used in cordage manufacture; it is quite strong, but is short, stiff, coarse, and rough. On account of its buoyancy, and because moisture does not affect it, rope made of coir is particularly well adapted for tow ropes.

65. Cotton rope is extensively used in small crafts for halliards, sheets, and sundry purposes, being much softer than manila. It is spun three-stranded the same as manila rope, but often comes braided. Cotton rope when braided is strong and durable but stiff and awkward to handle, especially when wet.

66. Care of Ropes.—Ropes should never be stowed away wet. Nothing will rot rope as quickly as to coil it, when wet, into a tight locker immediately below the deck with the hot rays of the sun beating down upon it.

67. Hawser and Cable.—A rope of three strands is called a *hawser*, *a*, Fig. 21. A rope of four strands is said to be *shroud laid*, as at *b*. Very large ropes are made by twisting three hawsers together to form a *cable*, as at *c*.

Ropes composed of four strands generally have a center, or core, consisting of a slightly twisted rope about which the strands are laid. This center rope, shown in *b*, is called the *heart*. Rope used on shipboard is designated by its circumference, expressed in inches, and is issued in coils of about 113 fathoms each.

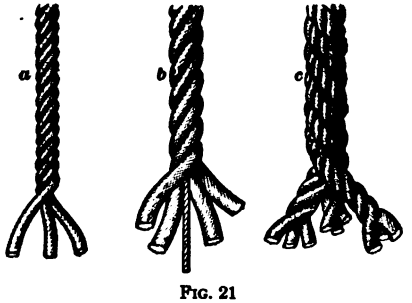


FIG. 21

68. Small stuff is the name given to various small ropes used on shipboard; they are distinguished by the number of strands and yarns used in their make-up. Thus, *ratline*, used principally for seizings and rattling down the rigging, is composed of three strands twisted right hand, each strand containing from four to eight yarns. *Spun yarn* is spun left hand, and consists usually of three yarns; it is used extensively for various purposes, such as seizings, mousings, to serve ropes, etc. *Rope yarns* are mostly made from condemned tarred hemp rope. *House line* is used for lacing sails, awnings, etc. *Marline* is a small kind of tarred hemp, used for serving (protecting) ropes and splices. *Twine* is used for whipping the ends of ropes and other small jobs.

69. Wire rope is made of iron or steel wire laid up like yarns to form strands, the strands in turn being laid up to form the rope in much the same way as a fiber rope. The number of strands composing a wire rope depends on the pur-

pose for which the rope is to be used; as a rule, six strands are used, laid up around a central strand of hemp known as a *heart*. The number of wires to a strand may be anywhere from three to fifty or more. To secure flexibility, the strands must be made up of a number of small wires spun around the hempen heart with a rather sharp twist.

Wire ropes are used most for standing rigging on modern ships. On pleasure craft, it is used for shrouds, stays, and for purposes where the rope is not required to pass through blocks or pulleys. Tow lines made of wire, when not in use, should be kept on a reel and great care must be taken when handling wire rope to avoid kinks and sharp nips. A single kink in the finest wire rope practically ruins the rope. To prevent corrosion wire rope is galvanized, but the necessary heating in the galvanizing process has the effect of partly annealing it and consequently reducing its strength. The best preservative for wire rope is raw linseed oil applied every other month.

SPLICING ROPES

70. Splicing is the operation of joining two pieces of rope so as to obtain one continuous piece with no appreciable increase of diameter at the splice. There are several kinds of splices but the principal ones are the *short splice*, the *long splice*, and the *eye splice*. The principle of all splicing consists of joining or "marrying" the strands, thinning them out, and tapering them so that the diameter at the splice is the same or only slightly greater than that of the rope itself. In the long splice, no increase in diameter is allowed. The only tools necessary for splicing hemp or manila ropes used for ordinary running

FIG. 22

gears are a *marlinespike* and a knife. The marlinespike is made of either iron or hardwood, is from 12 to 14 inches long, and about 1 inch in diameter at the thick end; the other end is sharpened to a blunt point. It is always operated by the right hand, while the left encircles the rope. After pushing the point through between the strands to be separated, the thick end is placed against the body of the operator; then, using both hands, the rope is twisted so as to render the work of opening the strands easy, as shown in Fig. 22.

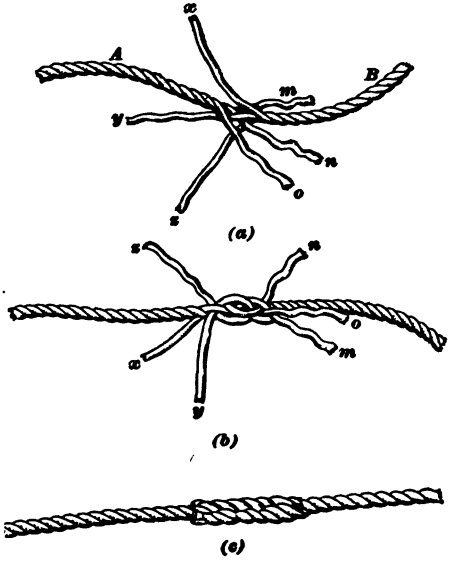


FIG. 23

71. Short Splice. To make the short splice, unlay the strands at the end of each rope for a distance about as shown in Fig. 23. This distance depends entirely on the diameter of the rope, but as the proportion will be the same for all diameters, the illustration serves as a general guide. Be sure to unlay enough; a few inches too much is better than too little, as the ends have to be cut off anyway. Then, place the two ends together, as shown in (*a*), so that each strand lies between two strands of the other rope. Hold the strands *x y z* and the rope *A* in the left hand, if the ropes are too large to hold thus, fasten them together with twine, then pass one of the strands, say *n*, over strand *y*, and, having made an opening, either with the thumb or with a marlinespike, in the manner shown in Fig. 22, push this strand *n* through under *x* and pull it taut; this operation is known as *tucking*. Proceed similarly with strands *m* and *o*, passing each over the immediately adjoining strand and under the next one. Perform precisely the same

operation with the strands of the other rope, passing each strand over the adjoining one and under the next, thus making the splice appear as in (*b*). In order to insure security and strength, the tucking must be repeated by passing each strand over the third and through under the fourth; then, after subjecting the splice to a good stout pull, cut off the ends of the strands, and the finished splice will appear as shown in (*c*).

72. In slings and straps used for heavy work, the strands should be tucked twice each way, and over one-half of each strand should be *whipped*, or bound, with twine to one-half

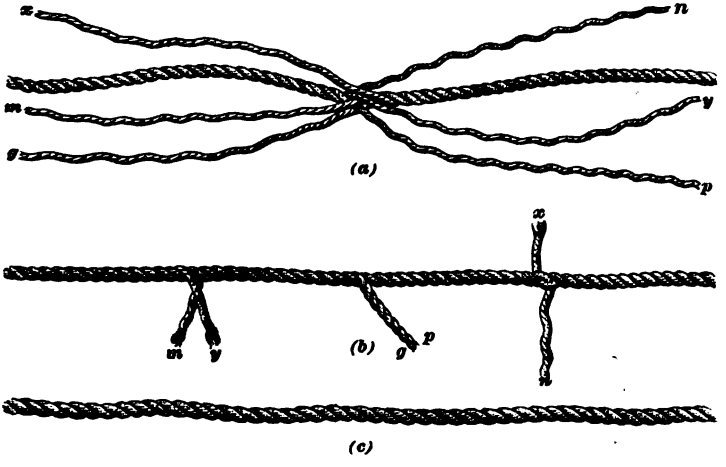


FIG. 24

of the rest, in order to prevent the strands from "creeping through" when the splice is taxed to its full capacity.

In the short splice, the diameter at the joint is greater than that of the rope, for which reason is is not a suitable splice where the rope is to be used in tackles and pulley blocks, or in places that will not admit anything larger than the rope itself. In such cases the long splice is used; this, when properly made, the untrained eye can hardly distinguish from the rest of the rope.

73. Long Splice.—To make the long splice, unlay the ends as before, but about three times as far, and place them together, as shown in Fig. 24 (*a*), in the same manner as for

the short splice. Then unlay one of the strands, say *x*, of the right-hand rope, and in the groove thus made lay the strands *n* of the left-hand rope, taking good care to give this strand the proper twist, so that it falls gracefully into the groove previously occupied by strand *x*. Do likewise with strands *y* and *m*, unlaying *y* gradually and in its place laying the strand *m*; the result is shown in Fig. 24 (*b*). Now, leaving the middle strands *p* and *g* in their original positions, cut off all the strands as shown in (*b*); then relieve strands *n* and *x* of about one-third of their yarns, and with what is left cast an overhand knot as shown—taking care that the knot is made so that the strands will follow the lay of the rope, and

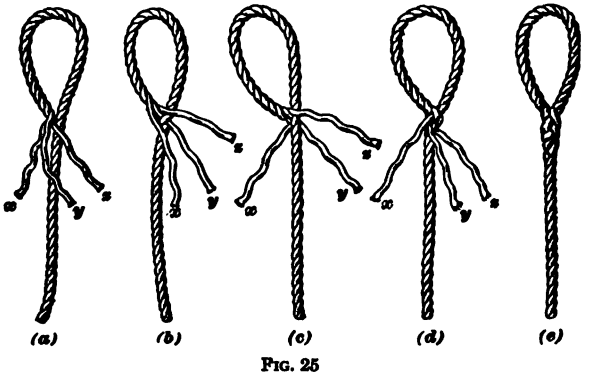


FIG. 25

not cross it. Pull this knot taut and dispose of the ends as in the short splice, by passing them over the adjoining strand and through under the next, cutting off a few yarns at each tuck. Proceed similarly with strands *p* and *g*, and *y* and *m*. The splice, when it is completed, appears as in Fig. 24 (*c*). Sometimes the overhand knot is made without first thinning the strands, and then split, and the half strand put through as described; but by doing so, the surface of the splice is never as smooth as by the other method, which, for strength and neatness, is second to none.

74. Eye Splice.—To make an eye splice, unlay the strands about as far as for the short splice, and bend into the required size of eye, as shown in Fig. 25 (*a*). Then tuck the end of

the middle strand *y* under one of the strands of the standing part—having previously made the necessary opening with the marlinespike—and pull taut, getting what is shown in (*b*). Push the strand *x* from behind, and under the strand on the standing part next above that under which the middle strand *y* was passed, so that it will come out where *y* went in, getting what is shown in (*c*); then pass the third strand *z* under the remaining free strand in the standing part, next to the one under which *y* was passed, getting (*d*). Pull the strands taut, and from each cut out one-third of the yarns; pass each remaining two-thirds over the adjoining strand of the rope, and then through under the next, as in the short splice; then cut off one-half of the yarns, and tuck the other half under its corresponding strand for the third time; give it a good stretching, cut off the ends, and thus complete the splice as shown in (*e*).

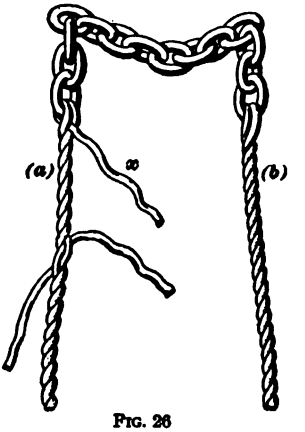


FIG. 26

In four-stranded ropes, the short and long splice are made essentially the same. In the eye splice, the first strand is tucked under two strands of the rope, the second tucking being done exactly as in the three-stranded rope.

75. Chain Splice.—To make a chain splice, unlay the strands of the rope and reeve two of them through the end link. Then unlay the third strand for about the distance shown, and in its place lay one of the other strands, the same as in making the long splice. Make an overhand knot and dispose of the ends in the usual way. Dispose of the third strand *x*, Fig. 26 (*a*), one of the two reeved through the link, as when making the eye splice, by tucking near the link. Cut off the ends, and the splice is complete as shown in (*b*). This is a very neat and strong splice, and can be used with advantage in connection with chains that are *tailed*, or lengthened, with a rope that has to pass through sheaves or places that do not allow any increase of diameter in the rope.

76. Splicing in Wire.—When making a long splice in wire rope, the same principles are followed as in splicing fiber ropes. The strands are unlaid, interlaced, and each placed snugly in the groove made by unlaying the opposing strand when the ends are tucked away in such manner as to follow the lay of the rope. Before unlaying the strands, it is advisable always to put on a good seizing at the extremities of the intended splice in order to prevent the rope from untwisting farther than is desired. The length of the splice depends, of course, on the size of the rope. When unlaying the strands, care must be taken to do so without taking out the turn. The strands may also be unlaid in pairs and singled up when married. The hemp heart is cut out close to where seizings are

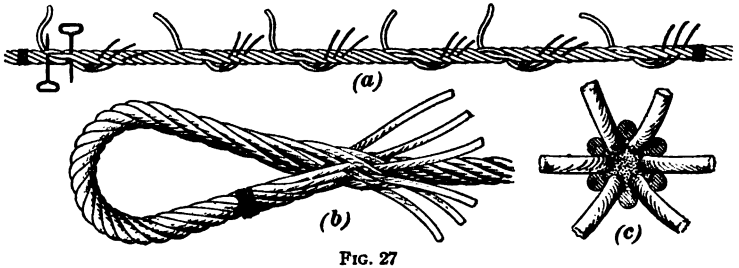


FIG. 27

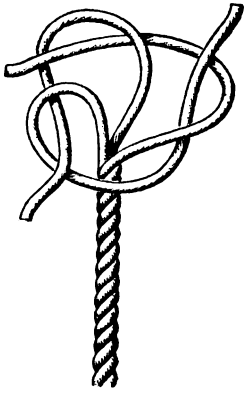
applied. Before tucking away the ends, each pair should be approximately at equal distances from one another, as shown in Fig. 27 (*a*).

77. The beginning of an eye splice in wire is shown in Fig. 27 (*b*). When the size of the eye is fixed, a seizing is put on as shown; then the standing part opened somewhat at the place where the tucking is to be done, by giving the rope a certain amount of twist. This will render the tucking comparatively easy. When tucking, have three strands on top and three strands underneath the standing part (assuming that the splicing is done horizontally), and dispose of them in such manner that each strand will come out in consecutive order, or as shown in Fig. 27 (*c*). It does not matter under how many strands (one or two) on the main rope they pass as long as they come out in their proper lay. The strands are now

tucked once or twice, taking care not to make the tucks too short, or the splice will be a lumpy one. Then the splice is hammered with a wooden mallet and the ends trimmed off snugly. The short splice is made in the same way as the eye splice.

78. Whipping a Rope.—Whenever a rope is cut to its required length the ends should at once be *whipped* to prevent the strands from fagging out. Nothing looks as bad about the deck as rope with ends resembling the mane of a mule due to lack of proper whipping. This is true of hawsers as well as the lacings of awnings; in fact, to any kind and size of cordage.

FIG. 28



(a)

FIG. 29

(b)

To whip a rope the end *a*, Fig. 28, of the whipping stuff (twine or yarn) is placed in the lay of the rope pointing toward the end of the rope; a few turns is then passed around the rope, binding the end of the whipping. Then laying the other end *b* on the turns already passed, pointing downwards, the remainder of the bight thus formed is passed around the strands and hauling it through the end part *b* is cut off snugly.

79. Wall Knot.—If no available whipping stuff is at hand what is known as a **wall knot** may be made by interjoining the strands, as shown in Fig. 29 (*a*). When the ends are drawn taut the finished knot will appear as in (*b*), holding

the strands firmly together and preventing the rope from fagging. This knot is useful also in cases where it is required to prevent the rope from unreeving.

BENDS AND HITCHES

80. In Figs. 30, 31, and 32 are shown a number of useful **bends** and **hitches.** The manner in which these bends are made will be evident from an inspection of the illustrations, hence only a few explanatory remarks concerning the use to which some of them are put will be needed.

The **reef knot,** shown in Fig. 30, is the best, simplest, and most used method of connecting the ends of two ropes, small-sized cordage. The **granny knot** is undesirable and unprofessional in every respect; it slips easily and is hard to untie.

For the purpose of attaching two ropes of different size, the single or double **sheet bend** should be used. The **double carrick bend** is sometimes used for bending two hawsers together.

The **bowline** is perhaps the most useful bend ever invented; it can be applied in various ways, from hoisting a man aloft to the bending together of two hawsers. To make it, the end of the rope is taken in the right hand and the standing part in the left and the end laid over the standing part. Then using the standing part a turn, or loop, is made around the end and the latter passed over and around the standing part and back through the bight again, thus completing the knot.

The **figure-of-eight knot** turned in a rope will prevent it from unreeving.

81. In Fig. 31 are shown a few methods of applying a rope to a hook. The **cross-hitch** is used for a sling or strap when the rope spreads away to its load; this hitch prevents the sling from slipping in the hook in case the load comes in contact with some obstruction while being hoisted.

The **Blackwall hitch** should be made with the end twice around the hook as shown, except for very light loads; experience has proved this to be the safest way, as with only one turn the end is liable to creep when subjected to a heavy strain,

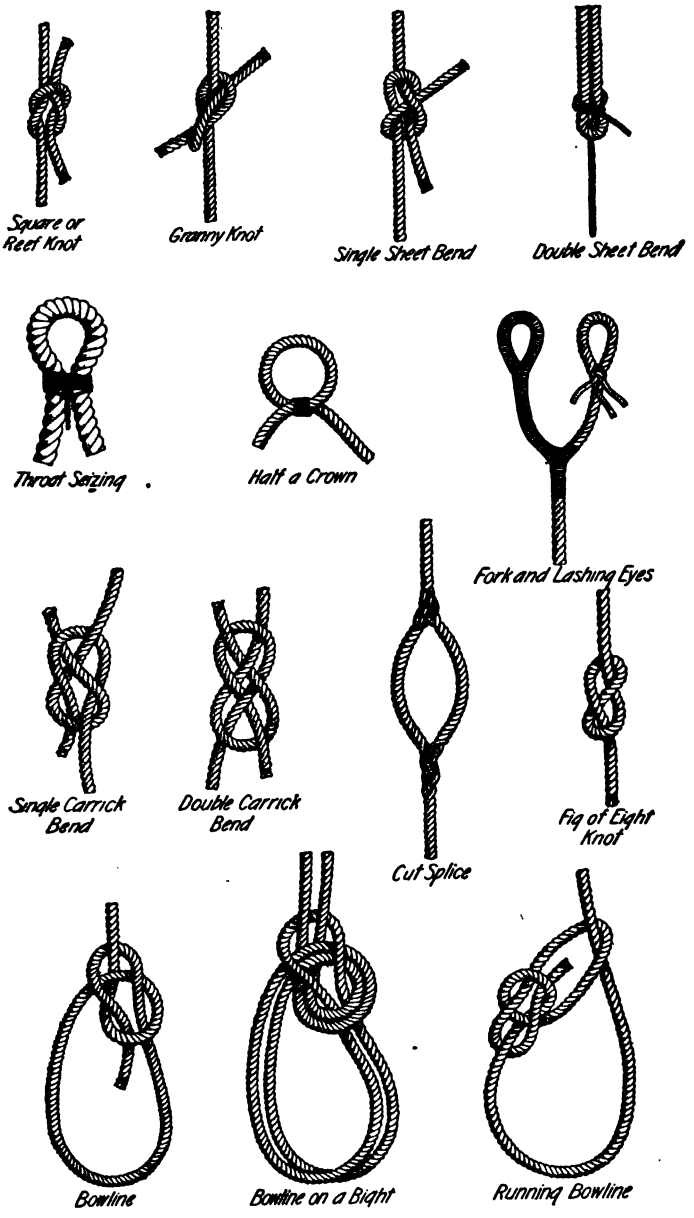

Square or Reef Knot
Granny Knot
Single Sheet Bend
Double Sheet Bend
Throat Seizing
Half a Crown
Fork and Lashing Eyes
Single Carrick Bend
Double Carrick Bend
Cut Splice
Fig of Eight Knot
Bowline
Bowline on a Bight
Running Bowline

FIG. 30

especially in damp weather when the moisture absorbed by the rope serves as a lubricant.

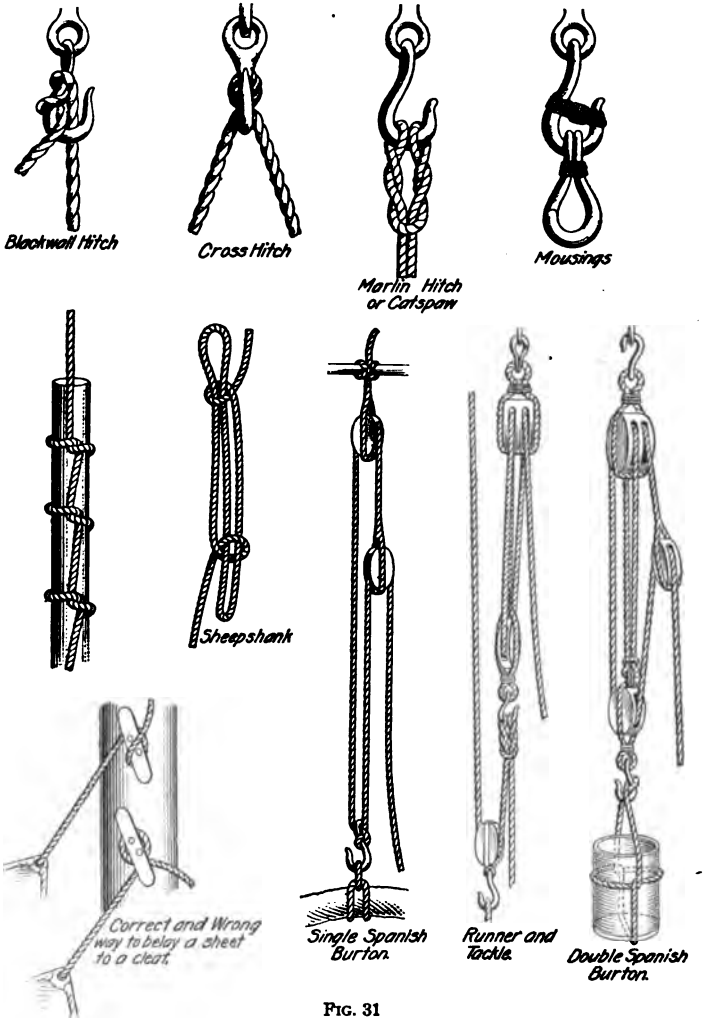


FIG. 31

The **sheepshank** is useful for shortening up a rope.

In this figure is shown also the correct and incorrect way of fastening a rope—say the sheet of a sail—to a cleat. If the

sheet is belayed as shown on lower cleat, the increased strain on the sail due to a sudden gust of wind, will jam the rope and render it difficult, if not impossible, to ease off the sheet.

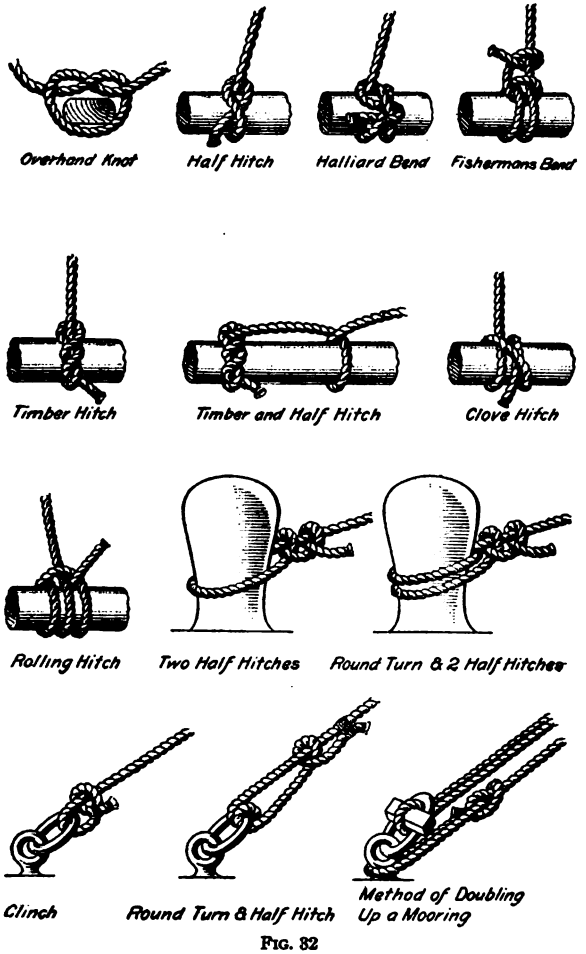


FIG. 32

The bends and hitches shown in Fig. 32 do not require any explanation, and can be made by referring to the illustrations. Learn and practice them all, in order that when needed they can be made quickly and without fumbling.

PARCELING ROPES

82. Any mooring rope will chafe and wear with the slightest motion of the boat when at anchor, or when moored to a

FIG. 33

dock, for which reason it is customary to protect the rope by canvas or burlap where it goes through bow chocks. In nautical parlance, wrapping the rope in this way is known as **parceling.** The parceling is done as follows: Wrap strips of old canvas,

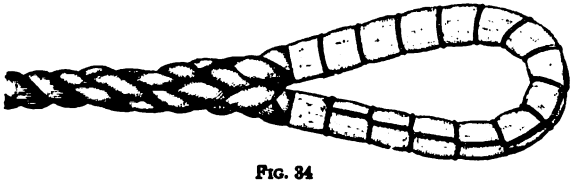


FIG. 34

about 2 inches wide, around the rope in a direction opposite to the lay of the strands, then secure them by twine or other handy small stuff, as shown in Fig. 33. If a loop is used to fasten the rope to the bitts, it should be parceled in the same way, as shown in Fig. 34. It is well to watch this parceling, and when worn out, to replace it by other strips of canvas to prevent injury to the rope.

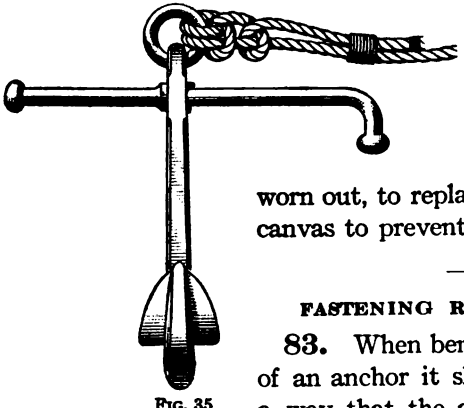


FIG. 35

FASTENING ROPES TO ANCHORS

83. When bending a rope to the ring of an anchor it should be done in such a way that the anchor will not be lost on account of a poor bend. The loss of an anchor when most needed may mean the loss of the boat, if nothing worse. The

proper way to attach a good-size rope to a heavy kedge anchor, for example, is to make a fisherman's bend as shown in Fig. 35. The bend is made by two turns of the rope about the ring with first half hitch encircling the turns, followed by a half hitch about the standing part, after which the end of rope is moused to the standing part by a piece of marlin.

FIG. 36

84. If the anchor is a light one, the rope should be bent on as shown in Fig. 36, taking two round turns about the ring and securing the end to the standing part by a bowline knot at about 1 or 2 feet from the ring. Before making the bend, the rope should be parceled with strips of canvas or burlap where it comes in contact with the ring to prevent chafing.

BLOCKS AND TACKLE

85. Blocks.—In nautical language, a **block** consists of a frame of wood or metal within which are fitted one or more sheaves or pulleys over which a rope may be led for convenience in applying power. Several types are shown in Fig. 37. Blocks for use on yachts and smaller craft are usually made of galvanized iron.

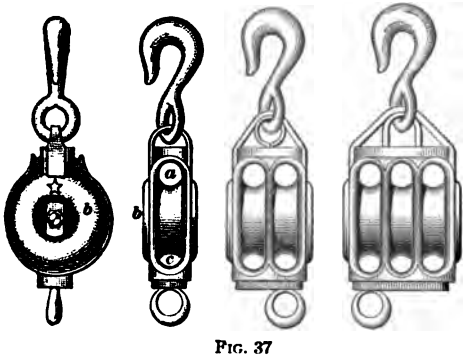


FIG. 37

The sheaves may be made of metal or some hardwood, preferably lignum-vitæ. The *swallow* of a block is the space *a* between the sheave and the frame. The side pieces *b* of the frame are known as the *cheeks;* and the end *c* of the block opposite the swallow is the *breech.*

86. Blocks are made in a great variety of design and size to meet the many purposes for which they are used. Special

types of blocks are made for use with wire rope. In Fig. 38 (*a*) is shown a *snatch block*, which can be opened for the reception

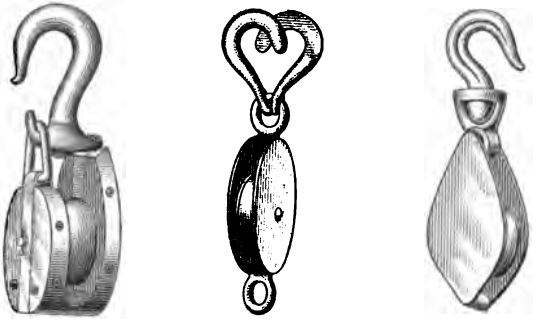


FIG. 38

of the bight of a rope; (*b*) is a block fitted with *sister hooks*, also called *match hooks;* and (*c*) is a *swivel block* used for a

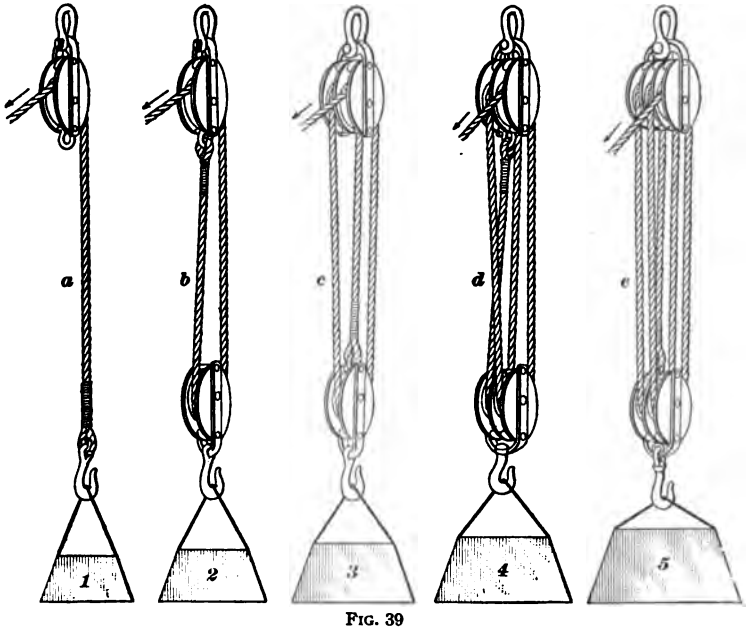


FIG. 39

number of purposes where the rope may lead in several directions.

87. Tackle.—When ropes are rove through blocks to multiply the power and attain the force needed to move or lift a load, the combined gear constitutes what is known as a **tackle.** Tackles are named according to the number of sheaves in their blocks as single, double, threefold, fourfold, etc.; they are also indicated by special names, as whip, runner, luff, purchase, Spanish burton, and so on.

The lifting power of tackles is determined by the number of sheaves over which the rope is rove. Thus, in Fig. 39, *a*, a weight equal to the load is necessary to lift it; in *b* the same weight lifts a load twice as big; in *c*, three times as big; in *d*, four times; and in *e*, five times. The speed, however, in *e* is only one-fifth of the speed in *a*.

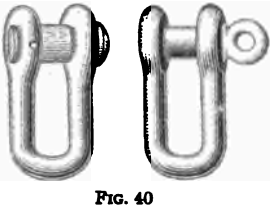


FIG. 40

88. Shackle.—A link in a chain cable that is fitted with a movable bolt in order that the chain may be shortened or lengthened or attached to an anchor is known as a **shackle.** In Fig. 40 are shown two ordinary shackles, one in which the bolt is fastened with a wooden pin and one in which the bolt is screwed in.

CANVAS

89. The fabric known as **canvas,** or **duck,** and used for sails, etc. of ships, is made from flax, hemp, or cotton. Sails of large ships are always of flax, while those of smaller craft and yachts are usually of cotton. Cotton canvas is used also for a variety of purposes, such as awnings, hammocks, and tarpaulins. Canvas is manufactured in long strips, or *cloths*, varying in width, from 16 to 24 inches for flax and from 20 to 42 inches for cotton, and in length, of from 40 to 80 yards. The cloths are made up in rolls called *bolts*. Variations in weight, strength, and fineness are indicated by numbers running from 1 to 10; No. 1 is the heaviest, strongest, and coarsest, and No. 10 the lightest and finest. The best grade of canvas used for sails of ships is made of flax 24 inches wide and sold in bolts of 80 yards. The best awnings are made of cotton 22 inches

wide, which is sold in bolts of 90 yards. Hammocks and bags are made of cotton canvas 42 inches wide, which is sold in bolts of 90 yards. For boat sails, cotton duck 28½ inches wide coming in bolts of 65 yards is generally used.

Good canvas is made of long, strong, clean threads evenly spun and well twisted, and in all grades the cloths should be closely and uniformly woven.

An 80-yard bolt of No. 1 flax canvas should weigh about 75 pounds and the successive numbers from this to No. 10 should weigh about 5 pounds less each. Thus, a bolt of No. 2 should weigh 70 pounds, one of No. 3 should weigh 65 pounds, and so on.

ANCHORS AND MOORINGS

ANCHORS

90. Ground tackle is a term applied to anchors, cables, warps, etc., used in securing a vessel to the bottom of the sea. There are many forms or types of anchors in use at the present time, the principal ones being shown in Fig. 41. The common, old-fashioned, kedge anchor has a *shank a*, two *flukes c*, and a *stock b*. When an anchor is lowered to the bottom, the function of the stock is to turn the shank so that one of the flukes will engage and bury itself in the ground, securing a firm hold by which the vessel is held. When not in use, the stock may be folded along the shank, the bend in one of its ends making this possible.

The objection against this type of anchor is that as one of its flukes is always pointing upwards, this fluke is liable to catch the chain or cable when the vessel swings and the anchor pulled out of the mud, causing the vessel to drag.

91. To avoid this, a number of patent anchors have been invented. These are so constructed as to lie close to the bottom and allow the chain to sweep over them. They have movable flukes and nearly all of them are stockless. Anchors of the stockless type have double flukes that flop either way

and get a firm grip of the bottom. On good-sized vessels this anchor is hove into the hawse pipe with the shank inside the pipe and the flukes close up to the sides of the bow, as

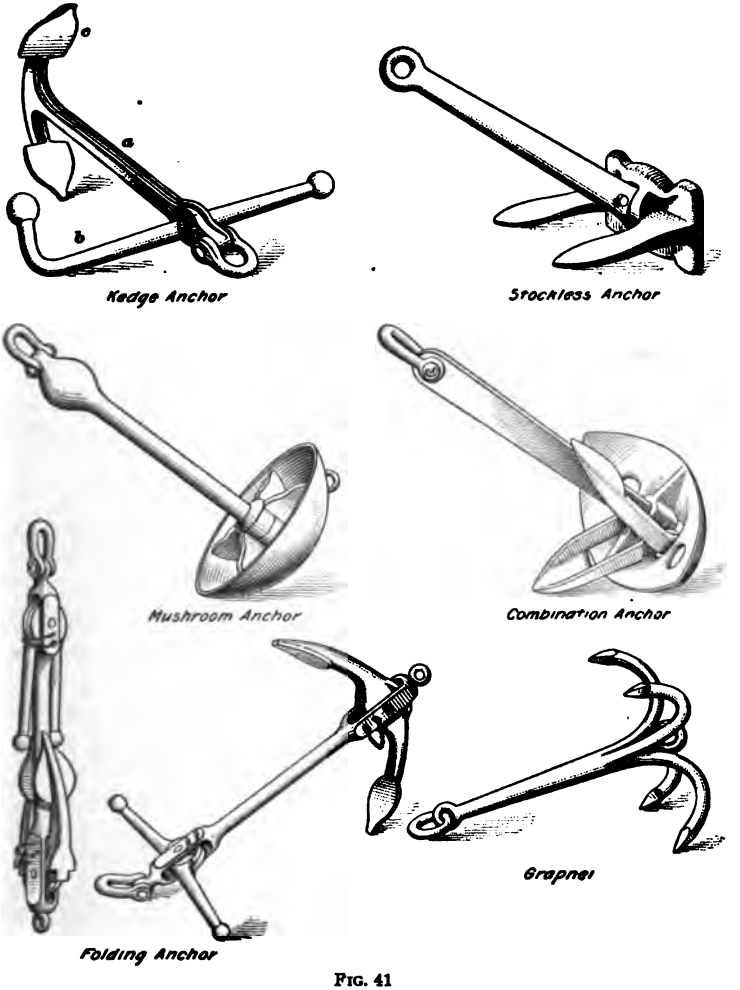


FIG. 41

shown in Fig. 42. For the purpose of anchoring buoys, moorings, light vessels, etc., the mushroom type is extensively used.

92. The grapnel, shown in Fig. 41, is a most useful and handy little anchor, particularly in localities where the bottom is covered with eel grass, while for recovering a lost anchor, chain, or rope by dragging along the bottom it is unsurpassed. Grapnels generally have two lines attached, a light line being fastened to an eye in the lower end of the shank so that if the anchor should become caught in a rock or piece of wreckage too heavy for the regular rope to lift, the grapnel can be released by being pulled backwards with the light line.

93. Motor-Boat Anchors.—Anchors for motor craft are many and varied, the folding type being the favored because of its convenience and the small space it occupies when stowed away. A cruising motor boat should be well equipped with anchors, chains, and mooring ropes, as in many cases the safety of the boat and its occupants will depend on the efficiency of the ground tackle carried. In Table I are given the weights, in pounds, of anchors that motor boats from 20 to 100 feet in length should carry, and the corresponding size of chain or rope attached.

FIG. 42

Anchors are not sold by their size but according to their weight, and this is usually painted in plain figures on the flukes.

94. The second and third columns give the weights of anchors in cases where a boat is provided with two anchors. As a matter of prudence, boats over 40 feet long should carry two anchors. The light anchor is used in still water with little or no wind blowing, the heavy one when anchoring in places where strong currents prevail or a high wind is blowing. The fourth column contains the weight an anchor should have when only one is carried. It will be noticed that this is a compromise between the light and the heavy anchors of columns two and three. The sizes given in the fifth column apply to

speed boats only, as a temporary anchor. In the sixth and seventh columns is given an approximate estimate of the size of chain cables and manila ropes used for anchors of corresponding size and weight.

95. Length of Cable.—The length, or amount of cable paid out should be five times the depth of water and never

TABLE I

SIZE OF ANCHORS AND CABLES FOR MOTOR BOATS

Length of Boat Feet	When Two Anchors Are Carried		Weight of Anchor When Only One is Carried Pounds	Weight of Anchor For Light Speed Boats Pounds	Size of Cable	
	Weight of Light Anchor Pounds	Weight of Heavy Anchor Pounds			Diameter of Material in Chain Inches	Circumference of Manila Rope Inches
20	10	40	30	20		$1\frac{1}{2}$
30	15	60	45	25		$2\frac{1}{4}$
40	20	80	60	30	$\frac{1}{4}$	3
50	25	100	75	40	$\frac{5}{16}$	$3\frac{1}{2}$
60	30	120	90	50	$\frac{3}{8}$	4
70	35	140	100		$\frac{1}{2}$	$4\frac{1}{4}$
80	40	160	115		$\frac{9}{16}$	$4\frac{3}{4}$
90	45	180	130		$\frac{5}{8}$	5
100	50	200	145		$\frac{3}{4}$	$5\frac{1}{2}$

less than three. In a strong wind it may be necessary to pay out more; the longer the cable the easier will a yacht ride out a gale and heavy sea.

For medium-size yachts, rope is the safer to anchor by, particularly in a choppy sea. A chain cable is liable to yank cleats and chocks and even start the windlass off its fastenings, whereas under the same conditions a manila rope, by its

tendency to give, will hold the boat without damage to fittings and gears.

An anchor rope should never be stowed away wet, as it will rot quickly. It should be coiled up and let dry thoroughly before being placed in its locker. Chain cables are usually hove in on a windlass, the weight of the chain causing it to run down in its locker without further attention.

MOORINGS

96. By the term mooring is meant all means and appliances by which a vessel is held in place at a dock or at anchor, maintaining its position despite the shifting of wind and currents. A vessel held by a single anchor may swing in any direction, causing her to get into positions that are dangerous or undesirable. A mooring consists, generally, in anchoring the vessel by two anchors, one in the bow, the other in the stern, by securing her to the dock by ropes, or by securing her to permanent buoys that are securely anchored.

Moorings for motor boats and medium-size craft are varied in arrangement according to local conditions and available material. In rivers and on lakes, motor boats when not in use are, as a rule, kept in regular boat houses, which, of course, is the best protection obtainable. But in the absence of boat-house facilities suitable moorings must be provided. In tidal waters due attention must be given to the rise and fall of the tide in order that the boat may not strike bottom at low tide or break its moorings at the rise of the tide.

97. Types of Moorings.—In Fig. 43 (*a*) and (*b*) are shown two ways of mooring a boat to a dock or float where the fall and rise of the water has to be taken into account. A wooden tripod made of heavy boards is slung about a stake driven in the bottom at a suitable distance from the float. To one of its corners a ringbolt is attached and through this ring is rove the stern line while the bowline is made fast to the float. The tripod will slide up and down the stakes with the fall and rise of the tide and thus keep the moorings at a uniform strain at all stages of the tide.

If the water is too deep to use a stake, the arrangement shown in (*b*) can be used. A buoy attached to a heavy chain is anchored at the proper distance from the float. When moored to this buoy and the float the weight of the chain will keep the boat clear of the float when the water rises and falls.

In cases where no tender is available to board the boat and cast off its moorings, arrangements simliar to those shown in (*c*) and (*d*) will be found convenient and practical. The

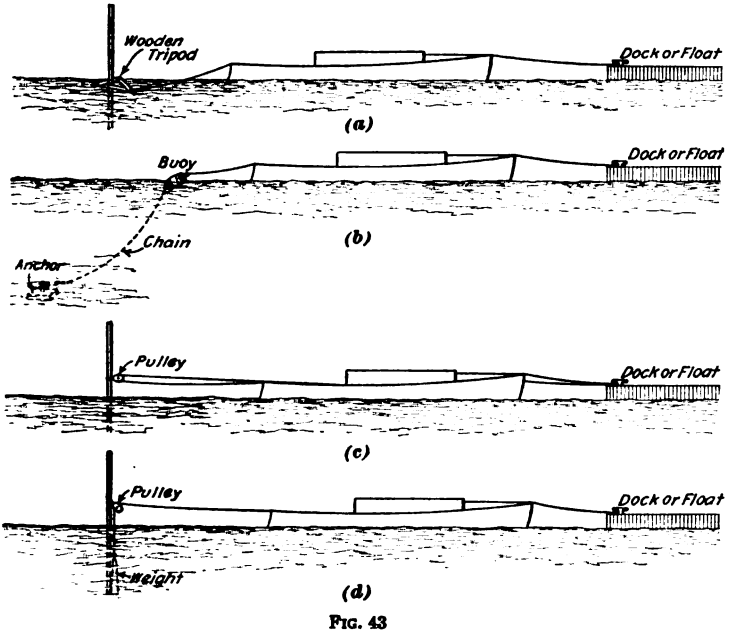


FIG. 43

stern line, rove through the pulley and fastened to the stake, is made long enough to reach the float. By making the end of this line fast to the after cleat or bitt while the boat is at the float, the boat may be pulled off at the required distance and kept there by belaying both lines to cleats on the float. The boat may thus be handled, moored, and unmoored directly from the float. Another handy method is to have the stern line attached to a heavy weight, as shown in (*d*), with sufficient line to insure the bow reaching the float when the boat is pulled

in. It is evident that the tension of the weight will keep the boat clear of the float.

98. When mooring a yacht alongside a wharf in a river where a strong current is sweeping down, care must be taken that adequate mooring lines are used in such manner as to prevent any possibility of the yacht getting away from the wharf. A line should be run from the quarter the full length of the yacht and made fast to bitts or cleats on the wharf, supplemented by another from the bow to a point well forward of the first line, as shown at *a*, Fig. 44. These mooring lines will carry the strain due to current, while the breast lines run from the opposite bow and quarter will keep her snugly against the dock. In cases where the rise and fall of the tide will affect a vessel moored alongside a dock, the mooring lines should be run similarly to those shown at *b*. Breast lines

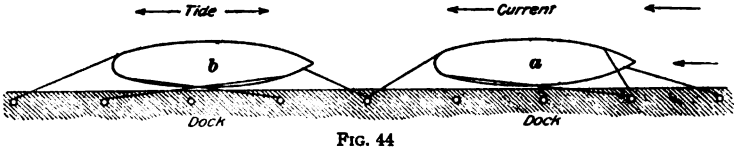


FIG. 44

run from chocks to close-by bitts or mooring rings on dock at high water are likely to snap or start something at the fall of the tide unless attended to in time.

99. Permanent Moorings.—In Fig. 45 are shown a number of mooring buoys used for permanent anchorage of a yacht in her home port. The best method in which to anchor these buoys will depend, in a great measure, on local conditions, but whatever form of anchor may be employed, it should be of such proportion and so secured to the bottom as to eliminate any chance of not fulfilling its mission in any stress of weather. The mushroom anchor, when once embedded in a mud or sand bottom, is truly reliable; it will stick under any kind of strain exerted by a yacht riding to its cable.

Improvised anchors, however, may serve the same purpose with equal trustworthiness. Thus, a large flat stone, a cast-iron freight-car wheel, or a concrete block, properly made, will make a first-rate mooring anchor.

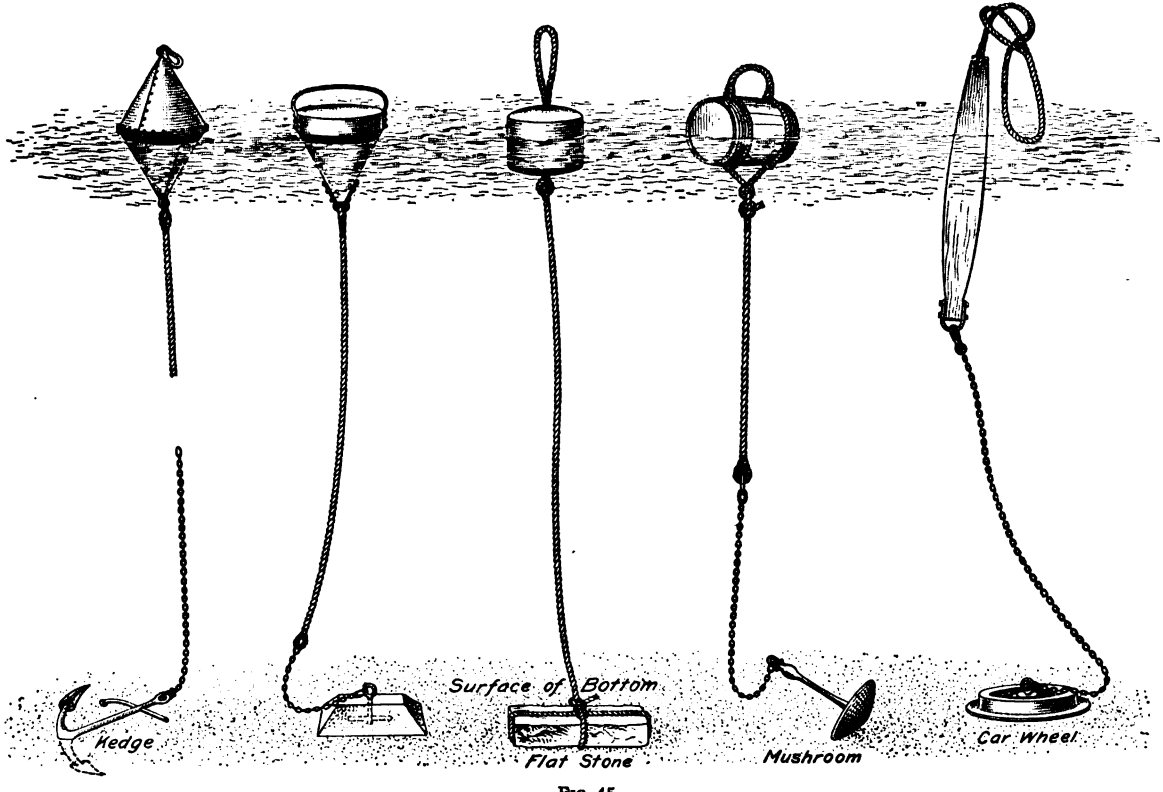


FIG. 45

If a flat stone is used, it should be drilled and fitted with an eyebolt to secure the mooring chain. A concrete block must be fitted in the same manner, which is conveniently done when the block is made by inserting in the soft cement a suitable bar and eyebolt, as shown in Fig. 45.

As a make shift and for temporary use, a rope securely tied to a suitable stone may be used to anchor a light buoy, but this is applicable only to small craft and in sheltered waters.

The kedge anchor may be used with advantage in rivers with a current running steadily in the same direction. In places where the yacht is liable to swing in any direction it is less suitable for reasons already explained.

100. The weight of the anchor should in all cases be dependent on the size of the yacht for which it is intended, but in the case of permanent moorings it is well to be in excess of the figures given in Table I. In every case it is better to have the mooring anchor too heavy than too light, for it is always easier to prevent an anchor from dragging than to make it hold after it has once begun to drag.

101. Riding Weights.—In exposed localities, special precaution should be taken to insure good anchorage for moorings; where heavy seas are likely to increase the strain on the cable **riding weights** should be attached to it. This weight, shown in Fig. 46, answers the same purpose as a spring. As a wave surges the yacht back the riding weight is lifted and the attendant jerk due to the action of the wave is reduced if not actually abated. The mooring buoy acts in a similar capacity though less effective by being dragged down as the wave lifts the yacht.

102. Use of Two Anchors.—In localities where tides create currents in both directions, or where the anchorage is open to heavy seas from several directions, a second fluke anchor may be employed in securing the mooring, arranged as shown in Fig. 47, with a riding weight attached to the shackle joining the two chain cables. This will insure a shorter radius of swing when the current or wind shifts the yacht from one

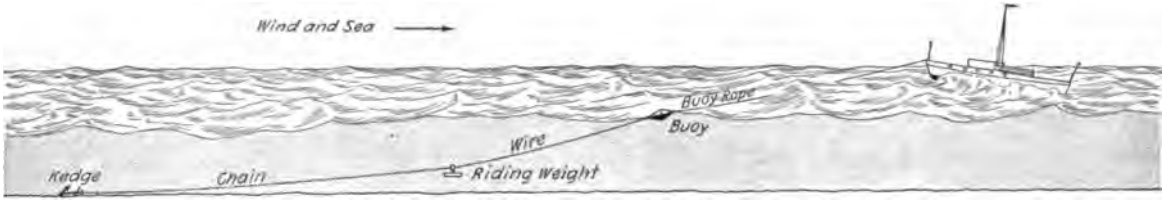

Wind and Sea
Buoy Rope
Buoy
Wire
Riding Weight
Kedge
Chain

FIG. 46

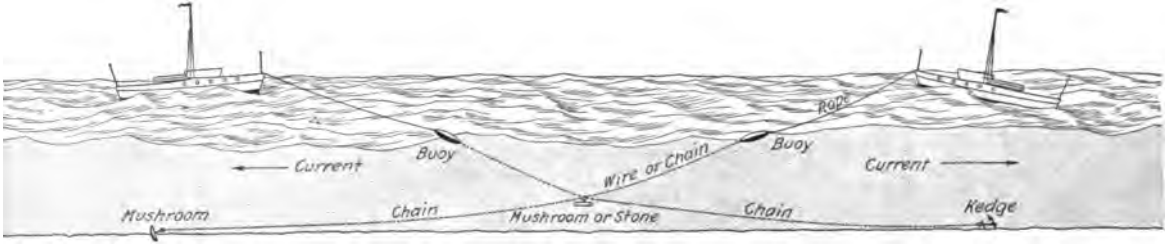

Rope
Current
Buoy
Wire or Chain
Buoy
Current
Mushroom
Chain
Mushroom or Stone
Chain
Kedge

FIG. 47

position to another and at the same time retain the advantage of a long riding cable.

103. Setting Helm of Anchored Vessel.—A yacht riding at a single anchor in a strong tideway, or current, is likely to sheer considerably, bringing the current first on one side and then on the other and driving across the stream until brought up by her cable, often with a violent jar to bitts or capstan. This may be prevented by putting the helm over as far as may be necessary and keeping it there, preferably with

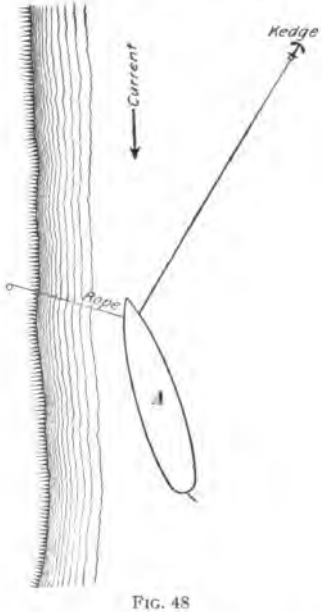


FIG. 48

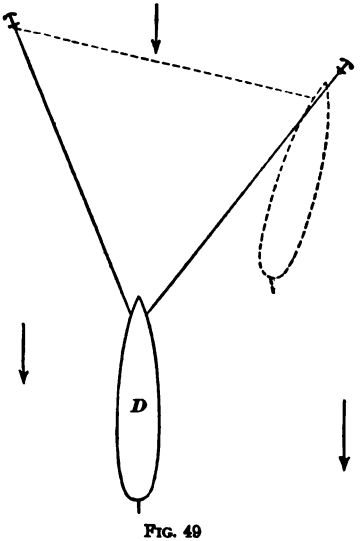


FIG. 49

the bow away from the anchor, as shown in Fig. 48. This puts a heavier tension on the cable, but a steady tension is preferable to dangerous jerks. If close by a river bank, a rope fastened to a tree, rock, or other suitable object on shore will aid in securing a comfortable anchorage where a strong current is running, as indicated in the same figure.

104. Dropping a Second Anchor.—When riding out a gale in an exposed roadstead it may often be necessary to let go a second anchor; this should be done with the engine going

ahead, sheering off from the first anchor, as indicated by the dotted lines in Fig. 49, in order that the second anchor may be dropped sufficiently far up against the wind and apart from the first to form a good-sized angle. After the second anchor is dropped its cable or hawser is paid out until the angle formed by the two cables is about 30°, at which angle the two anchors will act most efficiently, provided they are given enough cable.

LATITUDE AND LONGITUDE

LATITUDE

105. The **latitude** of any place on the earth's surface is the distance north or south from the equator measured on the meridian that passes through the place. Thus, if a place is situated at *A*, Fig. 50, north of the equator *E E'*, its latitude is the arc, or distance, *B A* of the meridian *P B P'* that passes through the place. It is named *north* or *south* latitude according to the situation of the place in relation to the equator; thus, the latitude of *A* is north because *A* is situated in the northern hemisphere. Again, if a place is situated at *C* in the southern hemisphere, its latitude is the arc *D C* of the meridian *P D P'*, and it is named south.

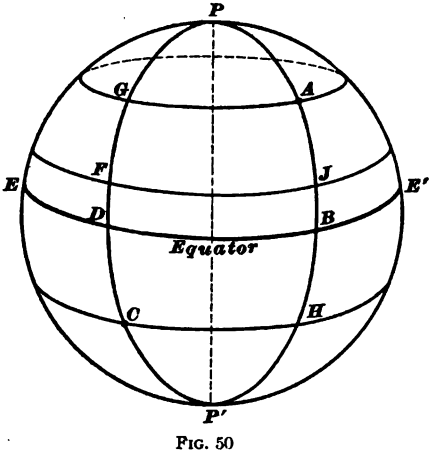


FIG. 50

Latitude is reckoned from the equator toward the poles in degrees, minutes, and seconds, and as the distance from the equator to either pole is 90°, there can be no latitude higher than 90°. When a ship is on the equator, its latitude is 0°; if at the north pole, its latitude would be 90° N; if at the south pole, 90° S.

106. The **difference of latitude** of any two places is the arc of a meridian contained between the two latitude parallels passing through those places. In Fig. 50, the difference of latitude between F and G is the arc $F\,G$ of the meridian contained between the latitude parallels passing through the two places.

All places situated on those latitude parallels have the same difference of latitude. Thus, the difference of latitude between A and F is the same as that between F and G.

The difference of latitude between A and C is the arc $G\,C$ or $A\,H$. The difference of latitude between B and F is the arc $F\,D$ or $J\,B$.

Difference of latitude is sometimes designated by the term *northing* or *southing*, indicating in which direction, north or south, a vessel has decresed or increased her latitude.

107. To Find Difference of Latitude Between Two Places.—If the places are both on the same side of the equator, or, in other words, if their latitudes have the same name, the difference of latitude is found by subtracting the smaller latitude from the greater; when the two places are situated on opposite sides of the equator, that is, when their latitudes have different names, the difference of latitude is obtained by adding the two latitudes.

Thus, in Fig. 50, if the latitude of G is 50° N and that of F is 20° N, the difference of latitude between F and G is equal to $50°-20°=30°$. Again, if the place H is in latitude 45° S, the difference of latitude between G and H will be $50°+45°=95°$.

EXAMPLE 1.—Find the difference of latitude between Boston, Massachusetts, in latitude 42° 22′ N, and Philadelphia, Pennsylvania, in latitude 39° 56′ N.

SOLUTION.—The latitude of both having the same name their difference is taken; thus,

Lat. Boston = 42° 22′ N
Lat. Philadelphia = 39° 56′ N (−)
Diff. of lat. = 2° 26′. Ans.

EXAMPLE 2.—The latitude of Cape Verde is 14° 43′ N; that of Cape St. Roque is 5° 28′ S; find the difference of latitude between the two places.

SOLUTION.—The latitudes being of different names their sum is taken; thus,

Lat. Cape Verde = 14° 43′ N
Lat. Cape St. Roque = 5° 28′ S (+)
Diff. of lat. = 20° 11′. Ans.

EXAMPLE 3.—The latitude of Southampton, England, is 50° 54′ N; the latitude of New York is 40° 42.7′ N; required the difference of latitude between the two places.

SOLUTION.— Lat. Southampton = 50° 54′ N
Lat. New York = 40° 42.7′ N (−)
Diff. of lat. = 10° 11.3′. Ans.

EXAMPLE 4.—The latitude of Rio de Janeiro is 22° 54′ S, and that of Buenos Ayres 34° 36′ S; required the difference of latitude.

SOLUTION.— Lat. Rio de Janeiro = 22° 54′ S
Lat. Buenos Ayres = 34° 36′ S
Diff. of lat. = 11° 42′. Ans.

108. When a ship sails north in northen latitudes or south in southern latitudes, she increases her latitude; but when sailing south in northern latitudes and north in southern latitudes she decreases her latitude. Therefore, when the difference of latitude and latitude from is given, the latitude in is readily found by addition or subtraction.

NOTE.—By *latitude from* is understood the latitude of the place the ship sailed from; by *latitude in*, the latitude of the place arrived at.

EXAMPLE 1.—A ship sails from a place in latitude 27° 15′ S, a distance of 320′ true north; required the latitude of place arrived at.

SOLUTION.—The ship having sailed north in southern latitudes, her latitude in is evidently less than her latitude from; as, 320′ = 5° 20′,

Lat. from = 27° 15′ S
Diff. of lat. (320′) = 5° 20′ N (−)
Lat. in = 21° 55′ S. Ans.

EXAMPLE 2.—A ship from the west end of the island of Madeira, in latitude 32° 48′ N, sails a distance of 98′ true north; find her latitude in.

SOLUTION.—The ship sailing to the north in northern latitudes, her latitude in is evidently greater than the latitude from; as 98′ = 1° 38′,

Lat. from = 32° 48′ N
Diff. of lat. (98′) = 1° 38′ N (+)
Lat. in = 34° 26′ N. Ans.

EXAMPLE 3.—A steamer from latitude 3° 8′ S runs a distance of 694′ north; find the latitude arrived at.

SOLUTION.—In this case, the steamer has evidently crossed the equator and is therefore in north latitude; as, 694′ = 11° 34′,

Lat. from = 3° 8′ S
Diff. of lat. (694′) = 11° 34′ N
Lat. in = 8° 26′ N. Ans.

EXAMPLE 4.—A vessel from Pensacola, Florida, latitude 30° 20′ N, runs 72′ in a southerly direction; what is her latitude in?

SOLUTION.—As 72′ = 1° 12′,

Lat. from = 30° 20′ N
Diff. of lat. = 1° 12′ S (−)
Lat. in = 29° 8′ N. Ans.

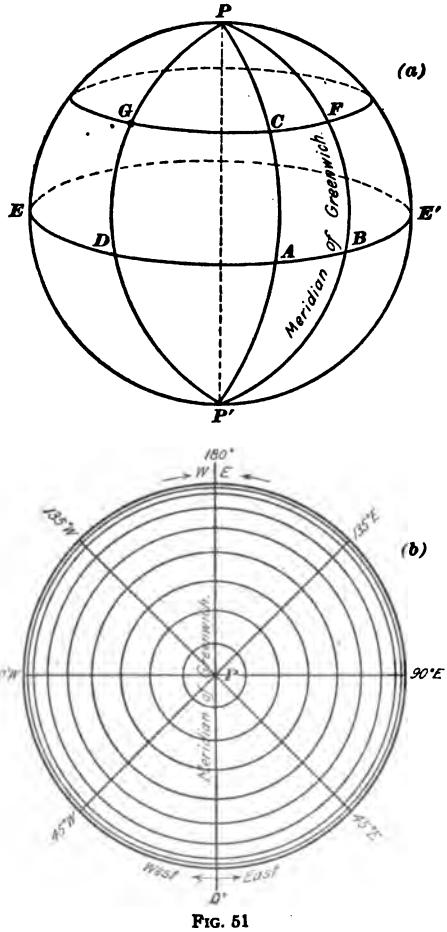


FIG. 51

LONGITUDE

109. The **longitude** of any place is the distance in arc east or west, measured on the equator, from the first meridian to the meridian passing through the place. Thus, in Fig. 51 (*a*), if $P B P'$ represents the first (Greenwich) meridian, the arc $B D$ of the equator $E E'$ intercepted between the first meridian and the meridian passing through G is the longitude of that place, and is named *west* because it lies to west of the first meridian. If G had been to the east of $P B P'$, its longitude would have been so many degrees *east*.

Longitude may also be defined as the angle at the pole subtended by the first meridian and the meridian passing through

the place. This angle $G\ P\ F$, the arc $G\ F$ of the parallel, and the arc $B\ D$ of the equator contain the same number of degrees, minutes, and seconds, although the linear distance of $B\ D$ is greater than the linear distance $G\ F$.

110. Longitude is reckoned from 0° to 180° *east* or *west*, beginning at Greenwich, but is never considered greater than 180° either way; if it exceeds 180°, it is subtracted from 360°, the result being taken and given the contrary name. Thus, longitude 186° W is equal to $360° - 186° = 174°$ E, but the former expression is never used. No place, therefore, can exceed 180° in longitude, whether east or west. Fig. 51 (*b*), which represents the globe looked at from above the pole P, illustrates the foregoing statements.

Besides being measured in degrees, etc., longitude is also measured in time; that is, in hours, minutes, and seconds, each hour being equal to 15°.

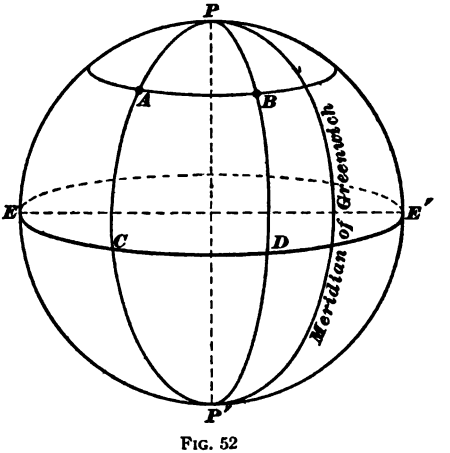


FIG. 52

111. The **difference of longitude** of any two places is the arc of the equator contained between the meridians passing through those places. Thus, the difference of longitude between the two places A and B, Fig. 52, is the arc $C\ D$ of the equator $E\ E'$ contained between the meridians $P\ D\ P'$ and $P\ C\ P'$ passing through B and A, respectively. When both places are in east, or both in west, longitude, the difference of longitude is equal to the difference between their longitudes expressed in time, or in degrees, minutes, and seconds; but if one place is in west longitude and the other in east longitude, the difference of longitude between the two is equal to the sum of their longitudes, or that sum subtracted from 360°.

EXAMPLE 1.—Find the difference of longitude, expressed in minutes of arc, between a place in longitude 5° 3′ E and another in longitude 16° 39′ E.

SOLUTION.—As both places are in east longitude, the difference of longitude is equal to the difference of their longitudes; thus,

1st long. = 16° 39′ E
2d long. = 5° 3′ E
Diff. of long. = 11° 36′

Expressed in minutes of arc, the difference is 696′. Ans.

EXAMPLE 2.—Find the difference of longitude between New York and Charleston, South Carolina; the former being in longitude 74° 0′ W, the latter in 79° 54′ W.

SOLUTION.—Both places being in west longitude their difference is taken; thus,

Long. New York = 74° 0′ W
Long. Charleston = 79° 54′ W
Diff. of long. = 5° 54′

Expressed in minutes of arc, this difference is 354′. Ans.

EXAMPLE 3.—One place is in longitude 1° 40′ W, another in 3° 20′ E; find the difference of longitude between the two.

SOLUTION.—As one place is in east, and the other in west longitude, the difference of longitude is equal to the sum of their longitudes; thus,

1st long. = 1° 40′ W
2d long. = 3° 20′ E
Diff. of long. = 5° 0′

Expressed in minutes of arc, this difference is 300′. Ans.

112. Relation Between Time and Longitude.—As the circumference of the earth is 360°, the sun, in making its apparent daily circuit in 24 hours, moves through 360°; hence, in 1 hour it moves through $\frac{360}{24}$, or 15°. When the sun has attained its greatest altitude, or is on the meridian of any place, it is noon there; hence, the time at any place 15° east of that meridian will be 1 hour past noon, and at any place 15° west of that meridian, 1 hour before noon.

Thus, at the instant of high noon at Greenwich, the time in longitude 30° W is 10 A. M. and in longitude 30° E it is 2 P. M. In other words, the time increases or decreases at the rate of 1 hour for every 15° of longitude, depending on whether the direction is east or west of Greenwich or some other meridian. This is shown in the chart, Fig. 53, where the heavy black

vertical line represents the meridian of Greenwich and the vertical light lines the meridians east and west, 15° or 1 hour apart.

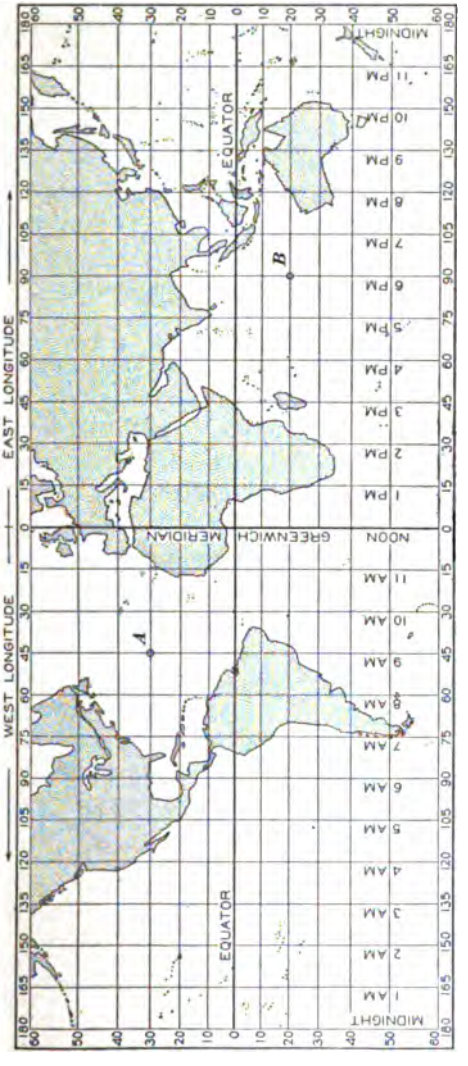


FIG. 53

Referring to this chart, suppose that it is desired to find the time at Philadelphia, Pennsylvania, when it is noon at Green-

wich. Philadelphia being in longitude 75° W, about, the time at that place would be 7 o'clock in the morning, and therefore the difference in time between Philadelphia and Greenwich is 5 hours, or 75°. Again, when it is 7 o'clock A. M. in Philadelphia it is 10 A. M. in longitude 30° W and 2 P. M. in longitude 30° E; and so on. From this it is evident that if the navigator knows the difference between this local time and that of the Greenwich meridian he has a means of determining the longitude of his ship. The greater the difference of longitude, the greater is the difference of time between any two places; from this, it will be seen that the relation between time and longitude are so intimate that they may almost be said to be identical.

113. Determination of a Position on the Earth's Surface.—From the foregoing explanations, it will be readily understood that any point, or place, on the surface of the earth is determined when its latitude and longitude are known. When the navigator finds his latitude, he knows how many degrees, minutes, etc. he is north or south of the equator, and by obtaining his longitude he knows how many degrees, minutes, etc. he is east or west of the first, or Greenwich, meridian. Then by consulting his chart he will at once be able to mark on it the exact position of his vessel. For example, if his latitude and longitude are, respectively, 30° N and 45° W, the position of his vessel is at the intersection of the given parallel and meridian, or at *A*, Fig. 53; if the latitude is 20° S and the longitude 90° E, its position will be at *B*, where the 90° meridian crosses the 20° parallel of south latitude.

MOTOR BOATS
(PART 1)

MOTOR-BOAT TERMS

1. Sheer.—Before taking up the study of the different models and types of motor boats it is well to have a clear

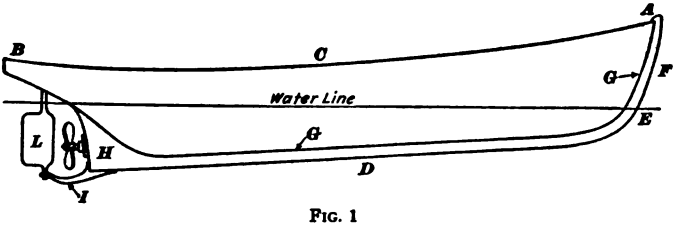


FIG. 1

understanding of the names of the various parts of which a boat is constructed.

In the side view of a motor boat, or the *sheer plan* as it is called, shown in Fig. 1, the curve of the top *A B C* is the **sheer.** Boats of older type generally had more of a curve or sheer than is now used. In Fig. 2, the sheer plan of a modern runabout

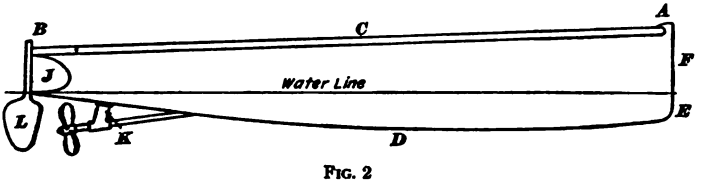


FIG. 2

is shown and the *straight sheer* of this is quite a contrast to the older *scoop sheer*, as it was called, in Fig. 1.

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From a structural standpoint, sheer is inconsistent to a racer and it is only since the hydroplanes have come into popular

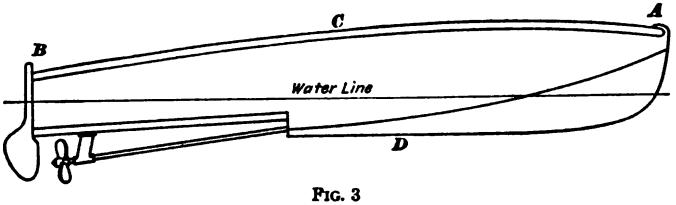


FIG. 3

use that the *hogged sheer*, shown in Fig. 3, has been adopted and old ideas discarded. At first it looked very odd to see this kind of a sheer but now it has come to be considered quite the proper thing. In older boats, this sheer was a sign of weakness in the structure of the hull due to poor design; it caused the ends of the boat to sag and often the resultant curve, formed by too straight a sheer line in conjunction with a very bluff rounded bow, produced a sheer such as that shown in Fig. 4, which is known as a *power-horn sheer*.

2. Freeboard.—The height from the water-line to the sheer line is called the **freeboard.** The boat shown in Fig. 1 has a low freeboard amidship, while in Fig. 3 it has a high freeboard. That part of a boat below the water-line is known as the *wetted surface.*

3. Draft.—The depth of water required to float the boat or the distance her keel is below the surface of the water at its lowest point is known as **draft.** A vessel that requires 6 feet of water to float her is considered a deep-draft vessel, while one that can float in 2 feet of water is a shallow-draft boat. The

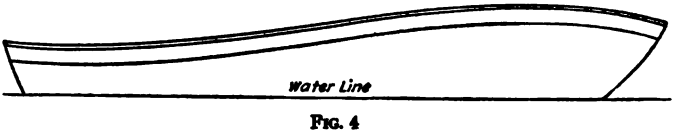


FIG. 4

draft, however, is relative to the size of the boat; a boat 12 feet long and drawing 2 feet is a deep-draft vessel for her size, while if her draft is 6 inches or less she is a shallow-draft boat.

4. Overhang.—By the term **overhang** is understood that part *B* of the hull that projects over the water, as shown in Fig. 1. A boat may have an overhang either at the stern or at the bow or at both ends.

5. Keel.—The main timber *D*, Fig. 1, on which the boat is built is the **keel.** Another view of the keel is shown in Fig. 5, which represents a section of the boat sawed in half. In Fig. 1, it will be noticed, the keel is a straight line, for which reason such a boat is called a *straight-keeled boat.* The sweep of the keel in the runabout, Fig. 2, is called a *rockered keel.*

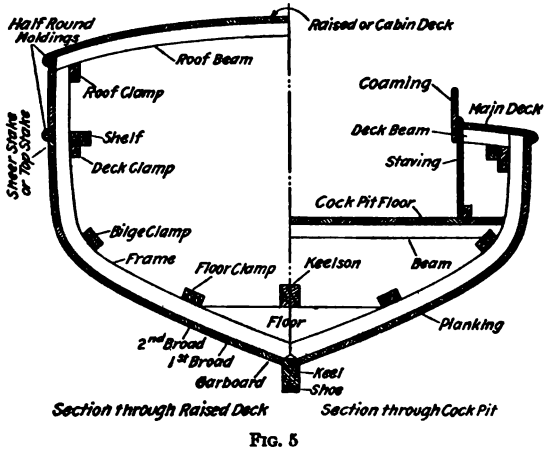


FIG. 5

The difference in the depth at which the keel is below the water-line aft and forward is the **drag.** The amount of drag is more in some boats and less in others. The effect of this drag is to make the boat run truer, for the deeper after end, offering more resistance to the water, acts as a drag. The boat in Fig. 2 has no drag at all; such a boat, when towed with a rope, will shoot off to one side or the other, owing to its being deeper at the bow. If towed stern first, the bow will act as a drag and the boat will tow straight. But it must not be supposed that because this is so, the hull of all boats should be as in Fig. 1. There is always a number of points to be considered in boat work. A long drag to the keel, as in Fig. 1, is good for boats

that are to make long straight runs with few turns; such a boat is easy to keep on a straight compass course. On the other hand, when a boat proceeds under her own power, the push on the propeller is aft and when the boat turns, the pressure on the rudder causes the stern to do the turning more than the bow, therefore a boat like the one shown in Fig. 2 has a stern that is easy to turn. It will swing much quicker than the boat with a keel like that in Fig. 1.

6. **Stem.**—The piece of oak to which the planking of the sides fasten at the front end of the boat is the **stem.** If the stem stands plumb up and down, as in Fig. 2, it forms what is called a *plumb-stem boat;* and if the boat is the same aft she is a *plumb-sterned boat,* which is generally abbreviated by simply saying that the boat is a *plumb-ender.* The boat in Fig. 1 has a *rounded stern* with a slight overhand, or *rake,* to it, the term *rake* meaning the same as slant; the round corner *E* where the stem joins the keel is called the *forefoot.* In Fig. 2, the boat is said to have a *deep forefoot,* while the one in Fig. 3 has a *rounded forefoot;* or, as the saying among boatmen goes, her forefoot is cut away a little.

7. **Dead Wood.**—The wood *H,* Fig. 1, bolted on top of the keel aft, is termed the **dead wood.** This term refers to all that wood attached outside and inside the planking, though it is generally used in reference to the inside portion, the part outside of the planking being termed the **skeg.**

By continuing the keel aft under the propeller, so that the rudder *L* is pivoted to it, the boat is said to have a *wooden rudder skeg.* If the keel does not extend aft, a metal casting *I* is bolted on for that purpose; the boat is then said to have a *metal rudder skeg.*

Where the edge of a boat's planking joins the backbone formed by the stem, keel, stern, and dead wood it fits into a notch *G,* Fig. 1, cut to receive it; this notch is known as the **rabbet.**

8. **Shape of Hull.**—If a boat is sawed in two, half way between the bow and stern, as in Fig. 5, the shape of the section

there will be known as the **midship section.** The form of this section of the boat largely determines the success or failure of the boat and consequently designers pay a great deal of attention in getting this part of the boat just what it ought to be. It must be full enough to have adequate carrying capacity for the weights the boat is to carry. It should be no bigger than is actually necessary, as then the boat will push aside more water in going ahead than is necessary, which is a waste of power. It must be round enough to roll easily and yet not too round. If too flat, it will recover too quickly in rough water and right itself with a quick jerk that is hard on both the boat and its occupants. It must be deep enough to have sufficient uplifting force and yet shallow enough not to be too cranky.

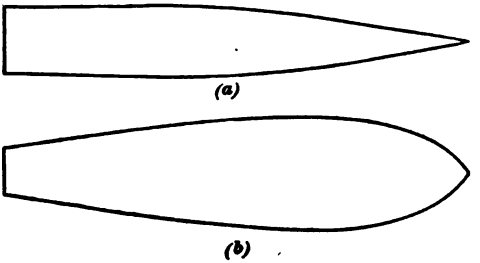


FIG. 6

9. Shape of Bows.—A long sharp-pointed bow, as in Fig. 6 (*a*), is called a *wedge-shaped bow* and such a boat is said to be very *lean forwards*. A boat shaped as in (*b*) is just the reverse; she has a *full deck line* forwards and has a *bluff bow*. When the bow is very bluff and the stern very narrow, it is known among fishermen and sailors as a *cod-head and mackerel-tail boat*.

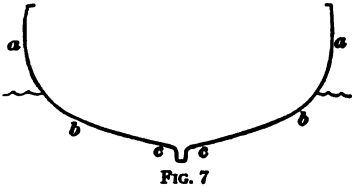


FIG. 7

10. Midship Sections. The names of the various parts of the midship section are the *top sides a*, Fig. 7; *bilge*, the bulge or rounded part *b* just below water; and the *bottom* or, as it is sometimes called, the *floor c*.

A number of different-shaped midship sections are shown in Fig. 8; these are by no means all, but they are the representa-

tives of the various models. Considering first the shape of the section as a whole, (*a*) shows a boat with considerable *dead rise*, as the angle between the floor or bottom and a level line is called. A great deal of the success of the boat depends on getting this *angle of dead rise* just right for the use to which the boat is to be put. If the boat is to be used where she will be tumbled about a great deal, this section keeps a fair proportion of buoyancy low down and produces a good sea boat.

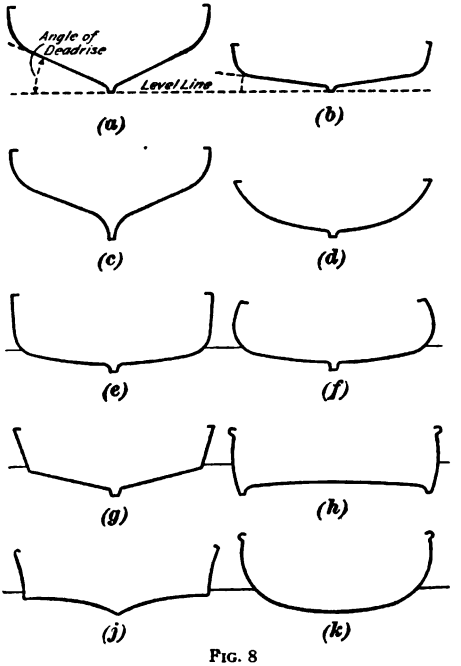


FIG. 8

A midship section like (*b*) has very little dead rise and its width compared to its depth is so great it would be called a *flat-sectioned boat* or a *flat-floored boat*. This shape of a section gives the greatest amount of flotation on the least draft and is used in shallow rivers, but it rights itself so quickly when amid waves that it is not an easy model for sea work.

View (*c*) shows an **S**-shaped midship section with a reverse curve or hollow in the *floor*. Sail boats use this shape more than motor boats, as it is a section that will resist being pressed leeward by the wind.

11. Views (*d*), (*e*), and (*f*) show three extremes. When the top sides flare out as in (*d*) it is a *flaring midship section;* this flare gives stability the moment a boat rolls a little by reason of the lifting tendency of every wave that rolls up against it. The boat shown in (*e*) is known as a *wall-sided boat* and that

shown in (*f*) has what is called a ***tumble-home side***, because the top of it rolls over, or ***tumbles in***. Such a side is largely used by small boats intended for use in rough water, as the waves get no chance to roll the boat. The tumble home is more apparent in the boat from amidship to aft so that the greatest round is at the stern; as the expression is "She has a big tumble home to her quarters." In the foreward end the reverse is the case.

12. A *skip jack*, or **V**-bottom midship section, is shown in (*g*); the sharp corner at the bilge is called the *chine*. In (*h*) is a *concave-bottom boat's* midship section; this section is used only on very fast hydroplanes, as at low speeds it is a very unstable shape. In (*j*) is a midship section that originated with the Fauber hydroplanes and is known as the *Fauber type*, though many other designers are now using this shape. The famous Dixie IV had a shape similar to this. When a boat is as round, as shown in (*k*), it is termed a *barrel-bottomed boat*.

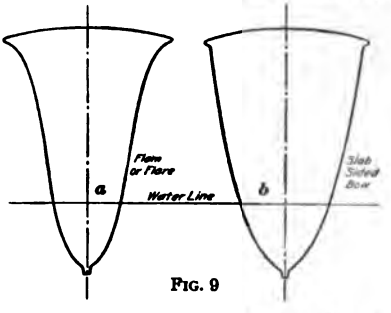


FIG. 9

At *a*, Fig. 9, is shown a shape of bow known as the *flam*. A boat with a heavy flare, or flam, to her bows throws the water out and away from the hull and prevents the boat diving too deep. A boat built with a *slab-sided bow*, as at (*b*), allows the water to fly straight up and go in showers all over the deck.

TYPES OF MOTOR BOATS

CLASSIFICATION ACCORDING TO SIZE, SHAPE, AND DESIGN

SIMPLEST FORMS

13. Skiff.—Motor boats are divided into a number of types according to their shape and size, and according to the use to which they are put. When subdividing boats according to their shape the first is the flat-bottomed skiff, or *sharpie*, which is the simplest and cheapest to build. A side view of one is shown in Fig. 10 (*a*), and a perspective in (*b*). These

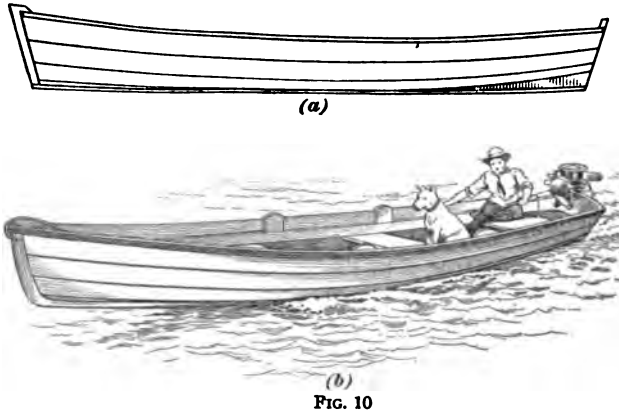


FIG. 10

boats are generally built by bending the two wide side planks around a midship mold and nailing the bottom boards in short pieces across from side to side as if building a box. The better grade of skiffs have beams, called *floors*, fitted across from side to side and the bottom boards nailed on lengthwise, or fore and aft, over these; this gives fewer seams and makes a smoother

bottom. For small ponds and shallow rivers and lakes where the water is comparatively smooth, the skiff is a most useful boat, as it can float in very shallow water.

To make the skiff model even more valuable as a shallow-water boat, certain types are now built with the shaft going aft from the motor inside of the boat and out through the transom, or back board, of the boat with a propeller whose lower blades only revolve below the bottom, the upper blades coming up out of the water. This style of boat, shown in

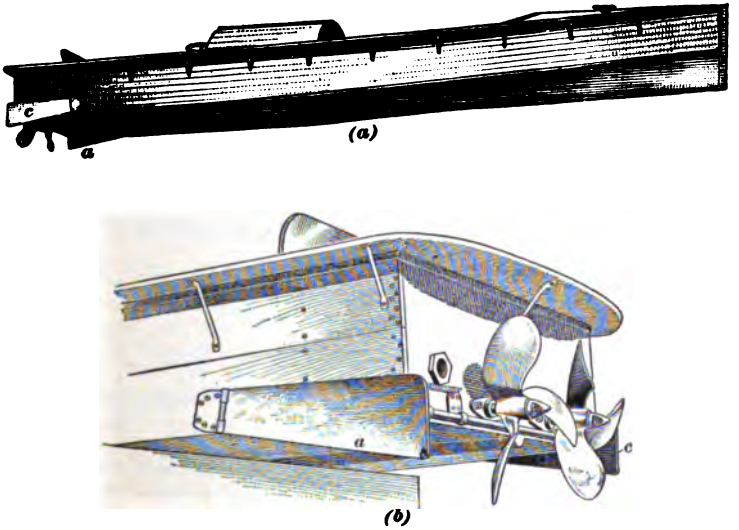


FIG. 11

Fig. 11 (*a*), is known as the "Viper" model and the propeller working in this manner is called a *surface propeller;* it is not wholly submerged but revolves at the surface of the water. There are two rudders *a* and *c* on these boats, one on each side, hinged flat against the boat's side and so fastened that they are somewhat deeper than the boat itself. In (*b*) is shown a stern view of this boat showing the arrangement of rudders and propellers. Such a boat can run in very shallow water as no part of the shafting extends below the bottom, as is the case in boats where the shaft comes slanting out through the bottom.

14. Skipjack.—Next to the skiff, in the matter of simplicity in building, comes the **skipjack,** a boat known by various names in different localities. It is shown in Fig. 12 (*a*) and (*b*) and has the same kind of flat sides as the skiff, but instead of the bottom being flat, it is deeper in the middle than at the sides. If turned up side down, the boat's bottom will resemble a house with a very flat roof, the ridge pole of the roof

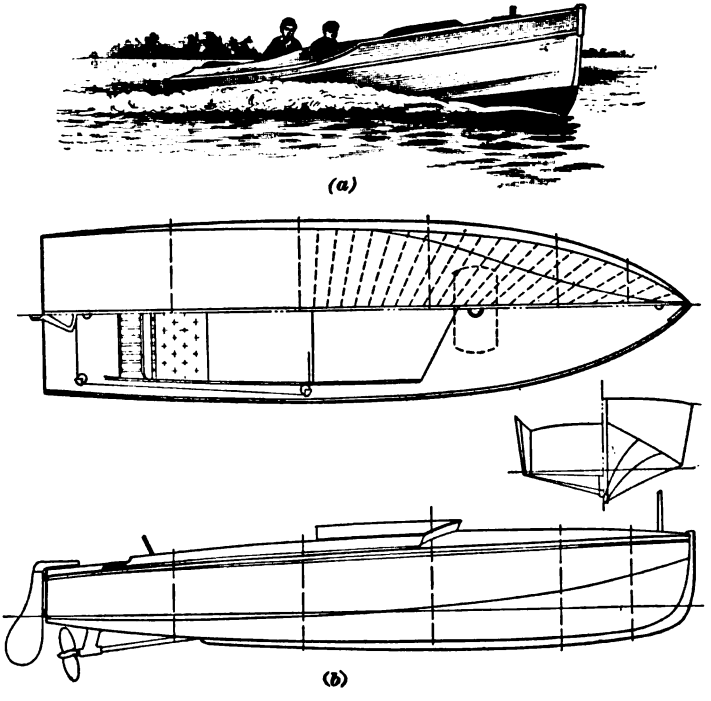


FIG. 12

corresponding to the keel of the boat. The skipjack model is not a new idea, but a modification of the old-time boats, made necessary to adapt it to use with a gasoline motor. It makes a fine sea boat as the bow is as sharp as that of a round-bottomed boat, and the edge, or *chine*, where the side and the bottom meet, if laid out to the proper sweep, add considerably to the stability of the boat. It has an additional advantage in caus-

ing the low waves to curve over and pass under the bottom of the boat with a decided up-thrust to the bow. The fastest motor boats of the hydroplane type are nearly all users of what is called the *skipjack bow.*

15. When gasoline motors were heavy pieces of machinery, it was impossible to get enough horsepower into a boat to drive her fast enough to *plane*, as the term that means sliding up on top of the surface of the water is called. But, with the increase in horsepower, it was found the boats slid over the surface at a speed that made the water seem as hard as ice, and so the boats were modeled to allow this thrust to raise them up. A round-bottomed boat will hardly do in this case, for when such a boat is set on a hard surface it is apt to roll over, but the skiff or skipjack model, or a combination of each is well adapted for this purpose.

The flat skiff bottom, while it was well suited for the highest speeds in absolutely smooth water, *spanked* so hard when there were any waves as to smash in the bottom planking. But a boat with a skiff after-end to give the flat sliding surface or plane in conjunction with the wedgelike bow of a skipjack, made an ideal boat for speeds of from 30 to 50 miles an hour.

The skipjack bow turns the water over like a plough curls it and then forces it under the boat; it does not throw it out away from the hull as does the ordinary round-bottom boat. This, of course, refers to the bulk of the wave. Any one seeing one of these fast boats, or a photograph of one, would imagine by the perfect cloud of spray they throw off to each side, that this was not the case, but it is. All that cloud of spray is a mere film of water shot up at the edge of the sides where at the speed the boat is going it is bound to tear the surface into spray, but the bulk of the water is undisturbed.

16. The **concave-bottomed boat,** or *hollow bottom*, Fig. 8 (*h*), as it is sometimes called, is a development due solely to the racing boat. It was found that by confining under the bow of a boat all the air and water that started and not letting any of it escape at the sides, as a round-bottomed boat does, that there was considerably less resistance. This section is

obtained by arching up the bottom of the boat in the middle, gradually flattening it out to a dead flat at the transom, and having a batten on each bilge, like runners, to confine the air.

Such a boat is not a good shape for ordinary use, but is a type much talked of at the present time, due to the speeds made by the "Sandburr II" and "Tech Jr.," two very fast boats that are of this type.

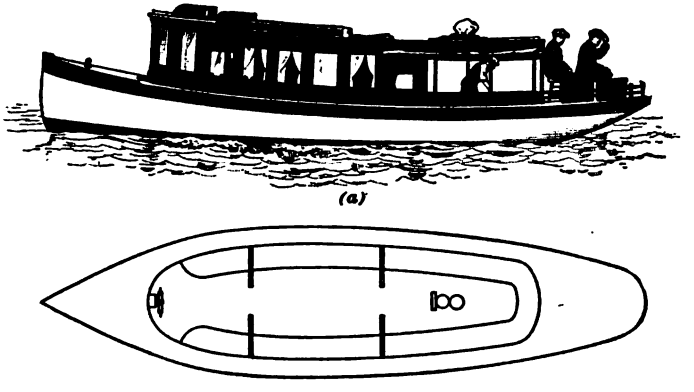
The round-bottomed boat, with its many modifications, is the boat in general use all over the world. The term *round*, however, does not mean the bottom must be a half circle in cross-section, but indicates any boat whose frames or ribs are bent in a fair curve from the keel at the center line to the deck edge. Just as a barrel is considered stronger than a square-cornered box, so the round-bottomed boat, for lasting qualities, has always been considered superior to the square-cornered skipjack. This is more true, however, in the case of sailing boats than it is with motor boats, for the latter have none of the twisting strains that the masts impart to the sailboats.

For cruising boats that are liable to be out in all kinds of weather, the round-bottomed type is particularly well suited. Boats of this type plough through the waves with more ease and roll more slowly than do the square-cornered boats, which right themselves with a quick jerk that at times becomes very uncomfortable.

17. Dory Bottom.—The type known as the **dory-bottom boat** is a combination of a flat- and a round-bottom boat. The sides are rounded as in the ordinary round-bottom boat, but instead of the sides going down to a keel they end at a flat, wide, bottom board, that reduces the draft of the boat considerably. It is cheaper to build a boat this way than with a round bottom and the flat bottom enables the boat to be placed on a fishing schooner's deck or to be run up on a sandy beach much handier than if it had a keel.

SHAPE OF STERN

18. Fantail Stern.—The use for which a motor boat is intended naturally determines the shape and proportions of the boat, and as improvements have been made in the propelling machinery, the boat's shape has been changed to meet modern requirements. Sailboats are not supposed to run up to a dock to land its passengers, but steamboats always have been. So for years steamboats have had, as a rule, a round after body. With such a shaped stern, they can start away from a dock; and as the stern slides along the dock, due to the bow being pointed out, there are no sharp corners to be bumped and splintered. Following this practice the early steam launches



(a)

(b)

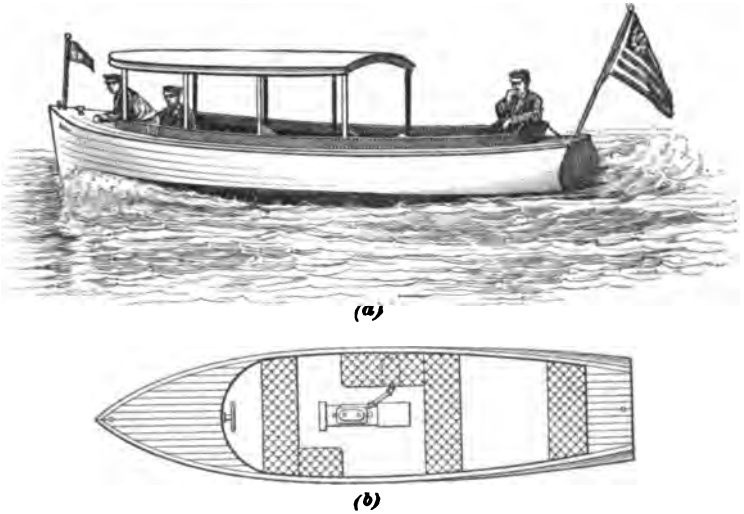
FIG. 13

in the navy used a round stern; therefore, it was but natural for the first launch hull built for pleasure purposes to follow that custom, and for years this was the universal style of stern on launches. The old gas-engine or naphtha launches were of this shape, having what is known as the **fantail stern**, which is shown in Fig. 13 (*a*) and (*b*).

19. Square Stern.—The framing and planking of a boat having a fantail stern is no easy task; so to cheapen them some boats were built without the fantail, which as it hung out over the water was known as the *overhang*. Boats that end square

aft, as in Fig. 14 (*a*) and (*b*), are called **square-stern launches** and the board that encloses the back end is known as the *transom*. This kind of a boat is often referred to as a *transom-sterned launch;* but the term *square stern* is more generally used.

20. What most inexperienced yachtsmen are apt to overlook is the fact that a certain shape of a boat that may be well adapted for one speed is totally unfit for a greater speed. The faster the boat is to run the straighter must be the lines in her after sections. The water will not close in quickly enough behind a rounded-up stern, but will tend to drag and pro-



(*a*)

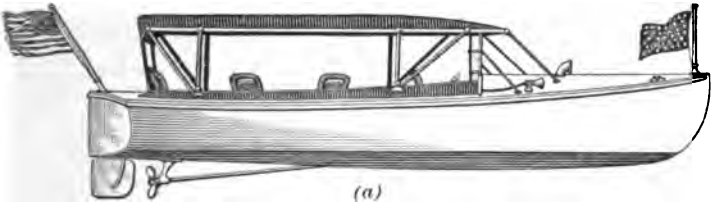
(*b*)

FIG. 14

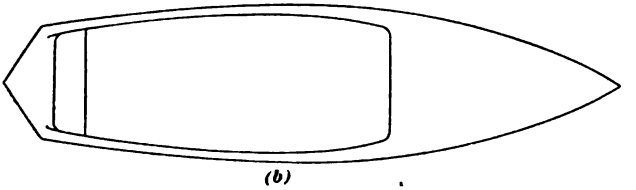
duce considerable dead water; a canoe model is very apt to be made so that it drags a lot of water behind it to the detriment of the boat's speed.

Hydroplanes are as square as a box aft, and, when starting up, drag a lot of water behind their transoms until they crowd up on the incline planes of their bottom sufficient to lift the stern up almost level with the water, then they go so fast that the water shoots clear at the stern with no drag at all. In order to have the wide stern with its wide quarters giving a good bearing on the water and yet to get away from having a

wide flat transom, some boats have a transom that, though it has a flat surface, is pointed like a wide-open **V**, Fig. 15 (*b*), the



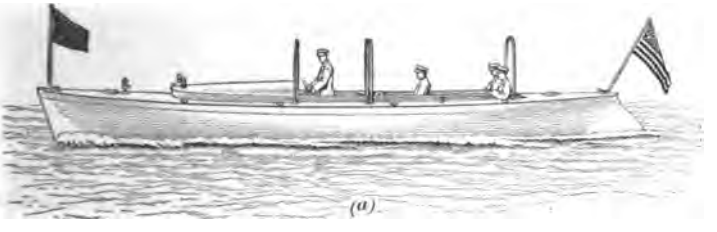
(*a*)



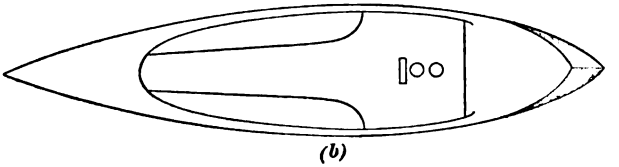
(*b*)

FIG. 15

rudder being hung as shown in (*a*). Such a **V** *stern* will back up as well as a canoe stern, looks racy, and permits of the hull being wide and flat aft for high speeds. A style of stern that was used a great deal on fast and supposedly fast boats was



(*a*)



(*b*)

FIG. 16

the old *torpedo-boat stern*, Fig. 16 (*a*) and (*b*), which had a deck that was much shorter than the boat on the water-line.

The *steamship stern*, Fig. 17, is used on the larger size of motor boats. It is a reproduction on a small scale of a large sea-going steamship's stern that ends at the water-line almost as

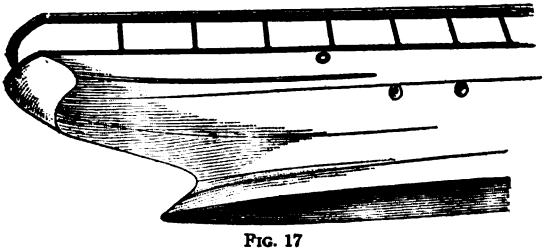


FIG. 17

sharp as the bow. Some yachts affect this stern in its outline even when the boat is wide and flat at the water-line as shown.

DEEP-WATER BOATS

21. The **dory**, Fig. 18 (*a*), is a good illustration of a boat with overhanging ends. It is a very old type of boat, having been used for years by the New England fishermen for fishing along shore and far out at sea on the Banks. The fishing schooners would carry six or eight of these dories stacked up one inside the other, forming what is known as a *nest of dories*. Being very light and buoyant, with sharp high ends, they can ride over a big sea safely. The bottom, though flat, is very narrow, coming to a point at each end and the sides have quite a flare; that is, the boat widens out a good deal at the top. As the fishermen construct the dories they are very simple and

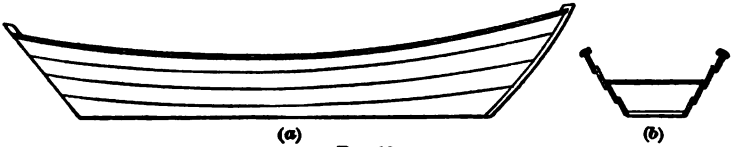
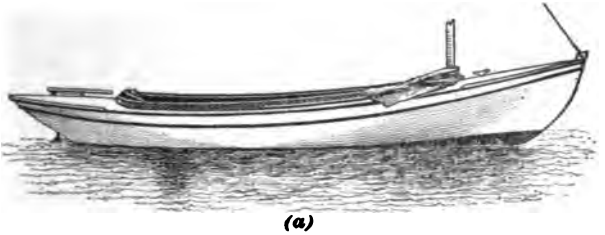


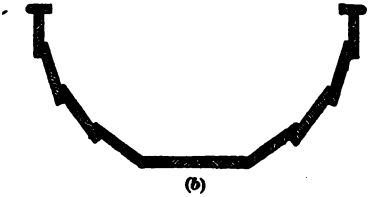
FIG. 18

cheap boats to build, the sides being nearly flat, as shown in this section, view (*b*), but when yachtsmen adopted the dory for pleasure sailboats, they had them built with their sides

rounded quite a little, as shown in Fig. 19 (*a*) and (*b*), in order to give them the required stability to carry sails.



(*a*)



(*b*)

FIG. 19

When the gasoline motors came into use, dories were again modified and became wider. The under body was made more full and the long overhanging ends of the original dories were shortened up, especially at the bow, so they are now almost the same as an ordinary launch bow. This departure from the original dory bow is plainly shown in Fig. 20.

22. The **whale-boat** model, shown in Fig. 21 (*a*) and (*b*), is another type that commended itself to many yachtsmen, as for years it had been used successfully by whaling ships to

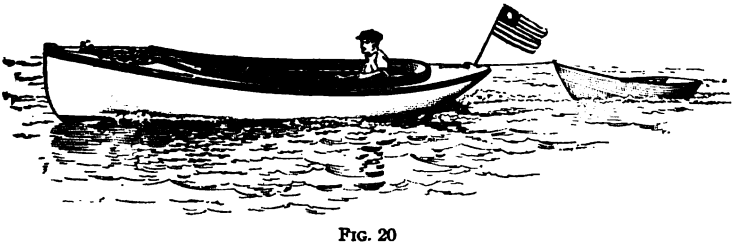
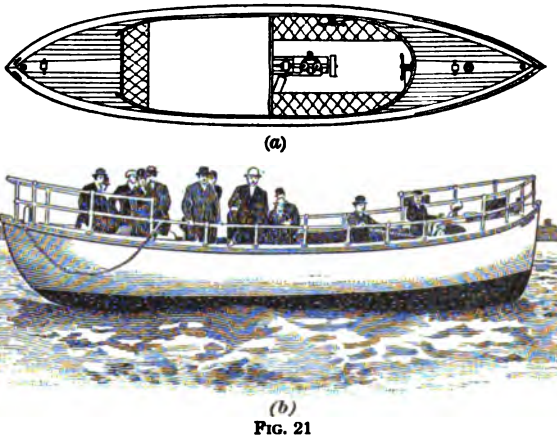


FIG. 20

hunt whales on the ocean. Men-of-war used to include a whale boat in their equipment of small boats, as with its sharp

ends and its light, strong construction it is an easy boat to row fast in rough water and sets high out of water.

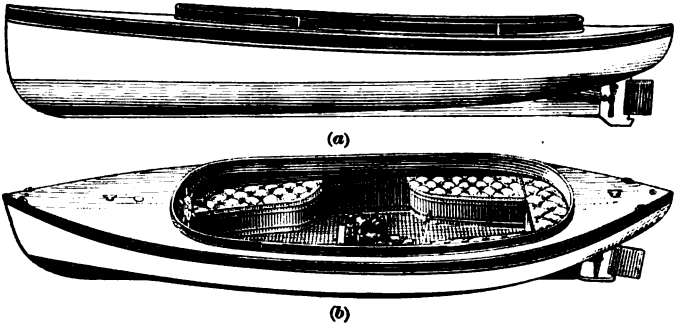


(*a*)

(*b*)

FIG. 21

This reputation for seaworthiness caused some men to insist on having their motor boats built with both ends pointed; but, with the weight of a motor and its gasoline tank, etc., the after end of the whale boat had to be gradually made fuller and fuller to prevent the boats squatting aft until it now no longer resembles the original whale boat. In its present shape, it is like a large canoe and there are as many men who call it by one name as the other. *Canoe model*, *whale-boat model*, or *double-*



(*a*)

(*b*)

FIG. 22

enders are all names referring to boats pointed at both ends, such as are shown in Fig. 22 (*a*) and (*b*).

Besides making a boat that will ride easily at anchor in rough water, the canoe-sterned boat is supposed to be a better model when a boat has to back up, but the cutting away of the stern to a sharp point aft removes those wide quarters that tend to stop a boat's rolling, with the result that though they are made double ended, the after end is made almost as wide and full-bodied as if the boat had a square or transom stern.

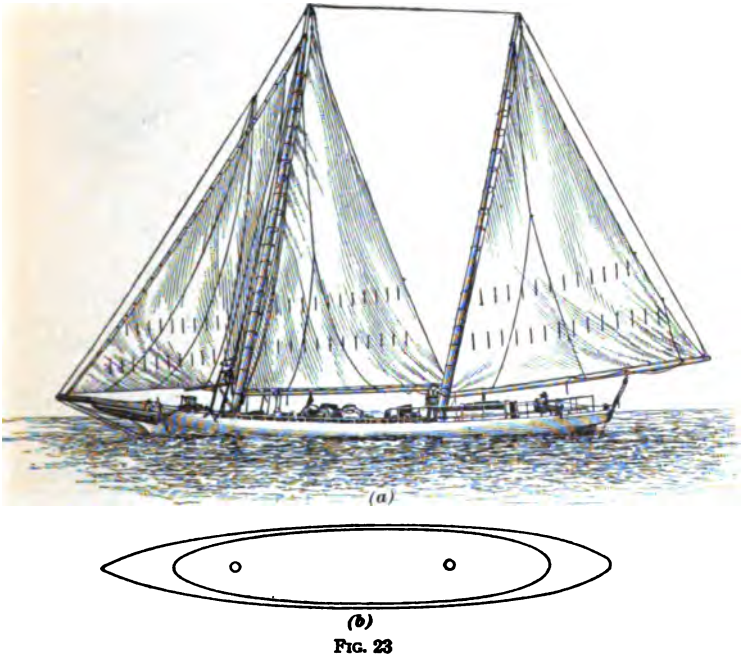


FIG. 23

23. Bugeyes or Dugouts.—A type of boat peculiar to the Chesapeake Bay is the **bugeye** shown in Fig. 23. Only the larger boats of this type are known as bugeyes, those of smaller size being called **pungies** or **dugouts.** The latter name better expresses what they are, as they are built by doweling together two or three tree trunks of large diameter and chopping them out to the shape of a long canoe pointed at each end and then digging out the inside. For years these peculiar boats used sails with two long raking masts carrying three-

cornered or leg-of-mutton sails and a jib; with a gasoline motor they make a very fast boat. A peculiarity of the bugeye, besides that of its queer rig, was the extremely long figurehead attached to the bow forward and which was generally very elaborately carved and painted.

24. Hampton Boats.—A remarkably good little sea boat, principally used by the Maine fishermen in lobster fishing, is

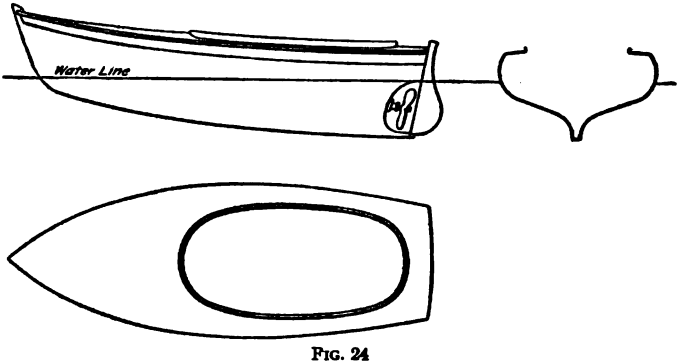


FIG. 24

the Hampton boat shown in Fig. 24. These boats are generally built about 20 feet long, have a high sharp bow, and quite a flat transom stern, with a very deep keel aft having an excessive drag. Another peculiarity is their construction. The planking is generally built up of narrow strips about 1 inch to 1½ inches wide all edge-nailed. Each nail goes through two planks and into the third one. Their hulls are usually modeled to ride the high seas encountered off the rugged coast of Maine.

SHALLOW-WATER BOATS

25. Seabright Dory.—Among boats used in very shallow water, and especially along the New Jersey coast, the craft known as *bank skiff*, or the **Seabright dory** is the best known. Its general make up is shown in Fig. 25. For a day's outing and for fishing, these boats are unsurpassed. They have a two-bladed propeller with the shaft coming out through the stern dead wood just above the bottom of the keel. By setting the

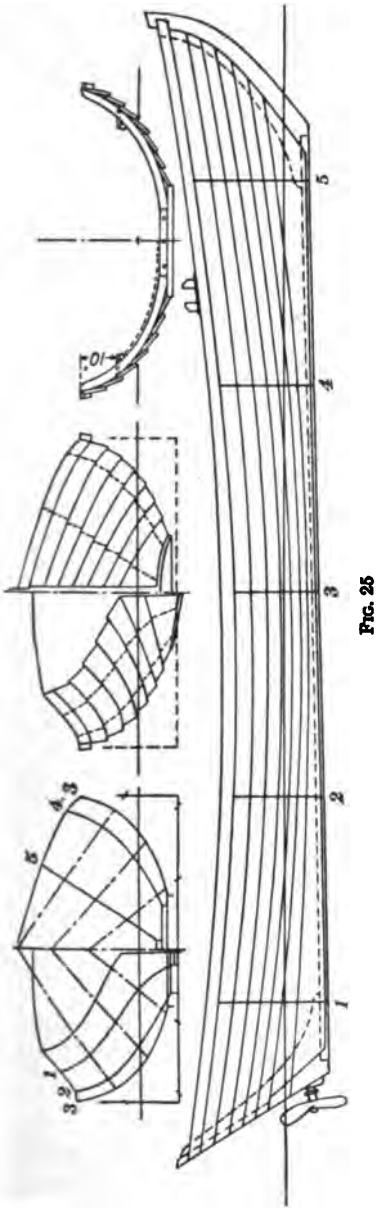


FIG. 25

propeller wheel so that the blades stand horizontally, the boat can be hauled up and down the sandy beach as it comes in or goes out through the surf. In some localities, these boats are known as *beach skiffs*. They have a flat bottom and are something like a dory, but are fuller in body, have more beam aft and far less rake to the stem and transom. Their proportions are 20 feet long by 5 feet wide, and as a rule they are fitted with about a 5-horsepower motor, which is enclosed in a box-like cover to protect it from spray.

26. Stern-Wheel Boats.—On the Mississippi River and its tributaries **stern-wheel boats** are used considerably. These boats have a wide flat-bottomed hull, the deck is generally extended out over the side of the hull, and is square or has a very full curve forward, as many landings are made by running the bow of the boat up against the river bank and dropping a gang plank to the shore. The deck houses on these boats are of all

descriptions according to the size and the use to which they are put. The river packets that carry freight have the deck clear and open except for a pilot house and a square box-like house aft over the motor to shed the water splashed up by the big stern wheel, which is carried on beams stuck out aft on either side. Both marine and stationary types of motors are used on these stern wheelers and the power is transmitted to the axle or wheel shaft either by sprocket wheels and chains or by gears.

So shallow and low are these hulls and so liable to twist out of shape that wire, iron-rod, or chain guys are set up tight over upright posts to strengthen the hull. Owing to the fact that the bottom amidships has the largest area and consequently the greatest sustaining surface, it is the ends of the boat that are

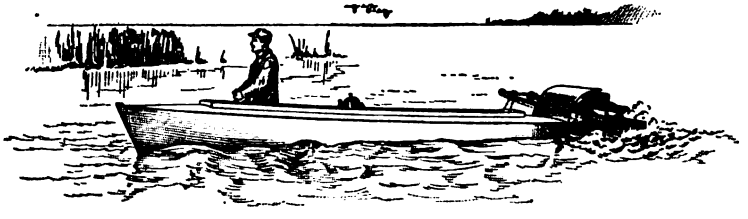


FIG. 26

likely to drop or sag. If the ends of a boat stick up and the middle drops, the boat is said to *sag*. If the middle rises and the ends droop, the boat is said to be *hogged*. As these chains, etc. are arranged to prevent the ends sagging, which is the more likely of the two evils to happen, they are called *hog chains*. In steamboats, where this support is framed of huge timbers, it is known as the *hog frame*. In Fig. 26 is shown a 16-foot stern-wheeler, with a 3½-horsepower gas engine, used in shallow water for towing duck boats.

27. Tunnel-Stern Boats.—Another form of shallow-draft boat is the **tunnel-stern boat**, which is a style largely built in England for export to foreign countries for use on such rivers as the Nile, the Amazon, and the rivers of China. In the United States, a similar type is extensively used on the shallow Florida and Mississippi rivers. The name is derived from the

fact that there is a trough-like tunnel built in the boat's bottom from about amidships aft, in which is placed a propeller. This

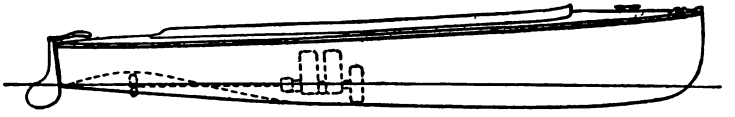
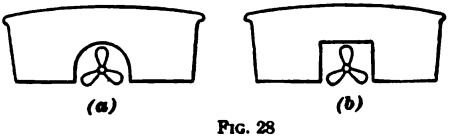


FIG. 27

tunnel is made so large that the blades of the propeller do not extend below the bottom of the boat. A large propeller is used by building the top of this tunnel considerably above the boat's water-line as shown in Fig. 27. When these boats were first built experiments demonstrated that an arched tunnel built in so that it just cleared the propeller, Fig. 28 (*a*), was more efficient than a tunnel built square, as in (*b*), but owing to the gain in efficiency being slight compared to the difficulty and expense of construction, most small boats are built with the square or box-section tunnel. It is of far more importance to build the tunnel in its fore-and-aft shape of such a sweep that the water can flow easily up into the tunnel and not be retarded at its after end. Some builders tried to increase the speed of their boats by building the tunnel straight aft from its highest point where the propeller works to the stern, as in Fig. 29. This plan, however, was not successful because the air that was thus admitted prevented the water from rising and submerging the propeller, which merely churned around half in air and half in water. By hinging a door to close the after end, Fig. 30,



(*a*) (*b*)

FIG. 28

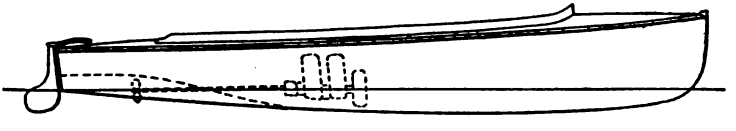


FIG. 29

this difficulty was overcome. But after the propeller had ejected the air and the boat was going fast enough to start a

solid stream of water following up the sweep of the tunnel, this door could be hoisted up flat against the upper part of the tunnel and the propeller remain submerged. For this reason, the tunnel-stern boats have the after end of the tunnel down even with or nearly even with the surface of the water.

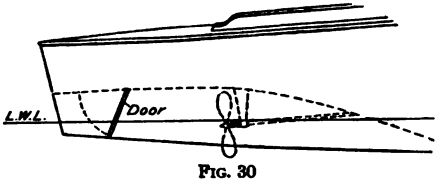


FIG. 30

28. Rift Climbers.—In some sections of the United States shallow rapids are called *rifts* and a type of tunnel-sterned or tunnel-bottomed boats constructed on the foregoing principle

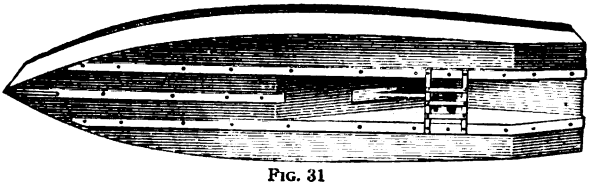


FIG. 31

are called **rift climbers.** These boats are built on the flat-bottomed skiff model with a square tunnel, as shown in Fig. 31. An iron grating across the tunnel protects the propeller from hitting anything and a removable square plate in the top of the tunnel gives access to the propeller so that it may easily be repaired or even replaced should it become damaged. The tunnel is built on straight lines, and is of such height as to take in the entire diameter of the propeller, allowing no part of it to extend below the bottom of the boat. It has a long, easy front slope, thereby reducing resistance to a minimum, and giving the water a free and unobstructed flow to the propeller.

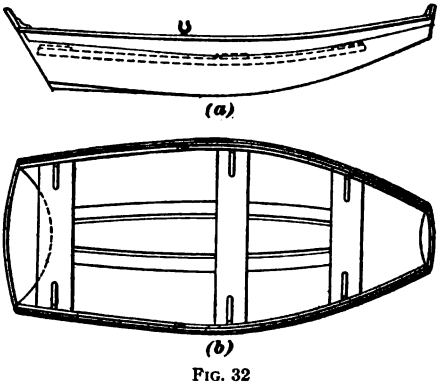


FIG. 32

29. Viking Skiff.—For use as a tender to yachts and other boats ascending shallow rivers where extreme low water prevents landing from the yacht itself the **viking skiff** is a valuable craft. Its light construction, wide beam, and small draft makes it an ideal tender in which to make landings, carry out anchors in case of grounding, and to fetch in game shot from the yacht and which without the skiff would be inaccessible. It is shown in Fig. 32 (*a*) and (*b*).

CLASSIFICATION WITH REFERENCE TO CABIN AND DECK ARRANGEMENTS

30. In addition to the classification already given, motor boats used as pleasure craft are arranged into various classes according to the use to which they are to be put, with no regard to the model whatsoever. The boat may be round- or flat-bottomed or skipjack, the hull may be a square-sterned, canoe-sterned, or any other shape, and the bow may be of any form whatever. This classification deals wholly with the living arrangements of the boats and the way the cabins and decks are built.

31. Open Boats.—Strictly speaking, **open boats** are only such boats as rowboats, skiffs, canoes, whale boats, skiffs used

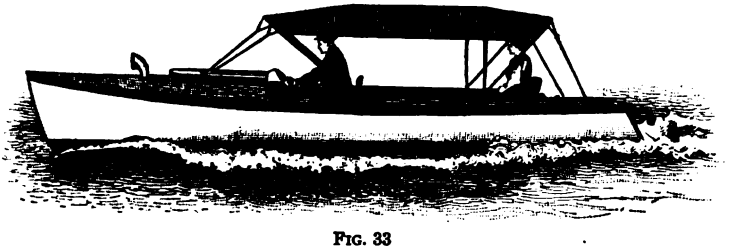


FIG. 33

to go through the surf on the Jersey beach, St. Lawrence river skiffs, and in fact all boats that have little or no decks that serve as a shelter. The term open boat is, however, often applied to what are, strictly speaking, *half-decked boats*, such as the old naphtha launches for instance, although these carried a light roof supported on stanchions with canvas drop side cur-

tains. Some people, however, refer to them as *standing roof* or *canopy-topped boats*, which is a more correct term for them. Another name sometimes applied to this class of open boat, shown in Fig. 33, is that of *day boat* from the fact that they are only provided with accommodations for people during the daytime and have no sleeping accommodations or house for shelter at night.

32. Runabouts.—The best type of a half-decked boat is the **runabout,** Fig. 34, which has a large open *cockpit*, as the open space in the boat where people sit is called, with either built-in seats, called *thwarts*, or willow chairs placed therein. The runabouts have their motors either in the cockpit with a short deck forwards and aft or in the forward end of the cockpit with, in some cases, the deck built over them and, in others,

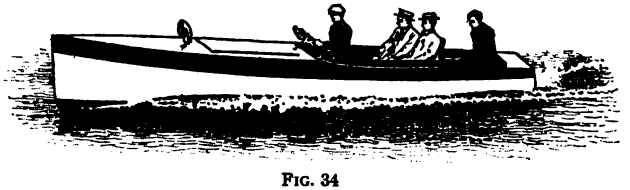
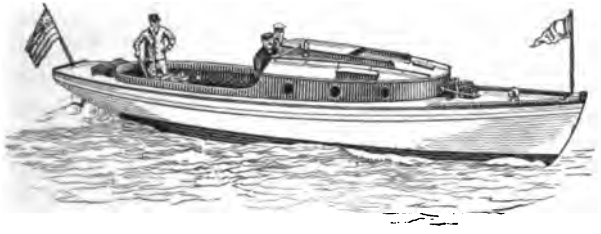


FIG. 34

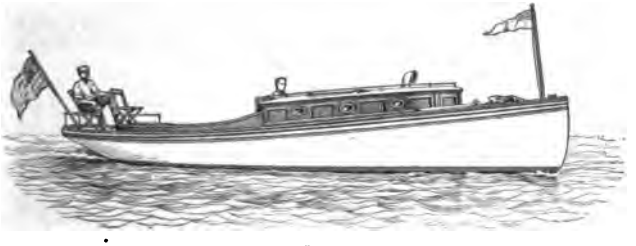
with hinged covers that raise up and permit a more ready access to the motor for adjustment. The better class of runabouts have a *bulkhead*, or partition, across the boat to strengthen it just aft of the motor. By means of wires and levers to the air and gasoline throttles, the timer, etc., all of these are manipulated at this bulkhead; the steering wheel, starting crank, etc., are usually attached to the same bulkhead which then forms what is known as a *bulkhead control.* The arrangement is similar to that on an automobile dashboard, with air-pressure gauges, speedometer, and even, in some cases, air starters.

33. Cabin Boats.—In the class known as **cabin boats** the variety of types is almost as great as there are styles of houses. The *trunk-cabin* boats, shown in Fig. 35 (*a*), (*b*), and (*c*) have cabins like those that were so popular on sailboats. These cabins have low wooden sides bent in a half circle forwards with oval glass windows or round brass port

lights, in the sides, that open and admit air. The roof of these boats is more or less arched, or *crowned* as the round-up of either cabin or decks is called, and is usually covered with canvas, which is well painted.



(*a*)



(*b*)

(*c*)

FIG. 35

The *glass cabin boat*, shown in Fig. 36, has a roof over all or half of the cockpit, with the sides enclosed in a row of glass windows that drop like a street-car window into pockets. This similiarity to the street-car top has led to their being

called *street-car boats*, in some localities. The term was originaly used as a misnomer by older yachtsmen but gradually absorbed by younger yachtsmen and retained. For sheltered waters, the glass cabin has many good features; with the windows open, the boat is practically an open boat and gives shelter enough when closed to afford all the protection one needs from rain and spray.

FIG. 36

34. Raised-Deck Cruisers.—For the purpose of securing a small craft that can be handled safely and comfortably in a rough sea, certain boat owners have developed a new type by having the forward part of their motor boat carried up flush with the sides. This serves a double purpose, as it allows the boat to go through rough seas without shipping any water over the bow, and at the same time it secures more room for the interior of the boat at but little increase in cost. To build a trunk cabin that is and will stay tight is not a cheap undertaking. Boats with their sides forwards carried up in this way are called **raised-deck cruisers**; an example is shown in Fig. 37.

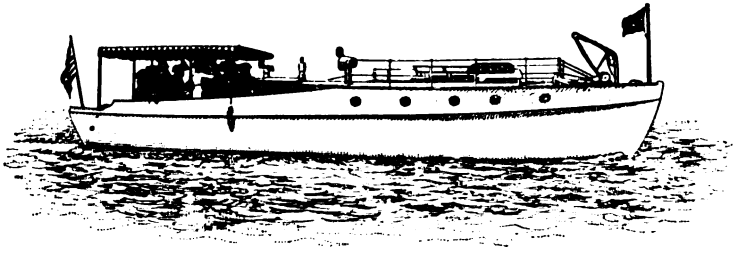


FIG. 37

At first this type of cruiser had the raised deck carried half way aft and even farther. This was found to give rather poor

ventilation below deck, for with the hot sun beating down on the roof the air in this apartment became hot and, with the heat from the motor, could not escape through the small windows. This led to the modification of the raised-deck cruiser used at present; it has a shorter raised forward deck and a narrowed-in trunk cabin with a row of big square windows along its sides to light and ventilate the cabin.

35. Bridge-Deck Cruisers.—With the early types of marine motors, the motor was placed where the operator could watch it and get at all parts readily, but the marine motor today is as positive and as certain in its action as the machines in automobiles. The result is that the motors are now placed amidship and across that portion of the boat. Over the motor is built a

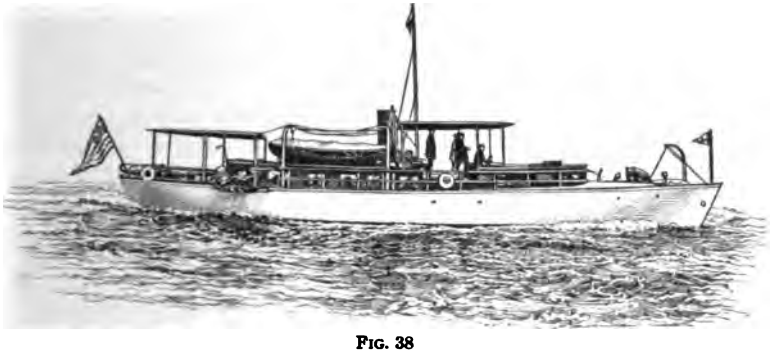


FIG. 38

deck, which greatly strengthens the boat at that point. It is on a level with the main sheer batter, or where the deck would ordinarily be if the boat's sides were not carried up to make her a raised-deck boat. The steering wheel and all the engine controls are led up to this *bridge deck*, as it is called, just aft of the forward raised deck. Aft of the bridge deck a trunk cabin is generally built to give headroom, light, and ventilation to the living quarters in the after end of the boat. Some bridge-decked boats, such as the one shown in Fig. 38, have a pilot house built on deck just forward of the bridge; this is set on the deck unless it stands up too high on account of the smallness of the boat when the pilot house is sunk into the deck about one-third its depth. The steering is often done from either the

pilot house or the bridge deck, but the inside gear is seldom used. This pilot house is generally used as a dining saloon, and the steering done from an elevated bridge aft of the pilot house.

36. Flush-deck cruisers, shown in Fig. 39, are vessels whose size enables them to have living accommodations with

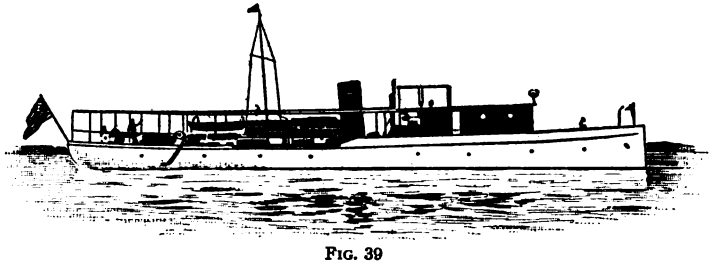


FIG. 39

full headroom below the main deck. They generally have a dining saloon forwards and a sort of living or smoking room aft; or there is one long deck house combining them all, with the steering deck placed on top of it.

CONSTRUCTION OF MOTOR BOATS

WOODS USED IN MOTOR BOATS

37. Every owner of a motor boat should study and understand not only his motor but his boat, how it is put together and the kind of wood that is best suited for the work the various parts have to do. There are many woods that are not suited for boat work where the alternate wetting and drying or long continual submersion call for certain peculiarities.

38. Oak and cedar are the two kinds of lumber most in use in yacht building. In boats where weight is no detriment, oak is the best because of its strength, durability, and the tenacity with which it holds fastenings. The live oak of our forefathers is now practically a thing of the past. Their ships lasted over 100 years. White oak is the best obtainable wood

today and is well adapted for keels, stems, floors, and frames. Cedar is used mostly for planking as it is very light, sinewy, has a soft fiber, is quite tough, and does not absorb much water.

39. Cypress is a good substitute for cedar; it has the same characteristics but is of a browner color and has a more pronounced grain, which with its varigated shadings of light and dark, is often used for interior decorations, the markings being very beautiful. It is used largely for planking, and while it absorbs somewhat more water than cedar it can be bought in planks much wider and longer than cedar can be obtained.

40. Yellow pine is invaluable for the lengths in which it can be had for large keels, or keelsons, or clamps. Large yachts use yellow pine for their planking, the species known as the long-leaf yellow pine being the best for boat work. Where strength and less weight than oak is wanted yellow pine answers the requirements, holding fastenings well also.

41. White pine, when clear of knots and straight grained is used largely for decks where, as in large yachts, the decks are to be left bright or unvarnished; but good white pine is scarce. Not long ago Michigan cork pine could be had in boards 2 feet wide and from 24 to 32 feet long, but at present this wood is difficult to obtain. It is easily cut, wears well, and makes exceptionally good planking if kept painted.

42. Spruce is used considerably in light racing boats for stringers and girders where strength and lightness are essential.

43. Rock elm is a fine wood for frames that are to be steamed and bent when hot. It becomes very pliable and yet is tough and holds its fastenings well.

44. Hackmatack, or **tamarack,** knees hold a fastening as good as oak and are lighter. Small boat stems are often cut from hackmatack knees and in large boats these knees are used to back up the oak stems and secure the stern to the keels.

45. Mahogany is strong, very light, and can be used in very thin boards, veneer in fact. It stands water well and

is used for planking on expensive launches, for decks, and for joinery work of cabins. Rails, covering boards, skylights, and interior bulkheads and trimmings are often made of this wood. It stands well in the sun, takes a smooth finish, and when stained and varnished gives a rich-brown color that is handsome in contrast with other woods. For planking, teak is an excellent wood, but is used sparingly on account of its high cost, being imported from Africa and the East Indies.

46. The foregoing are the principal woods used in the construction of a boat's hull. Such woods as **hickory** and **ash** do not stand well in the wet condition met with on a boat. **Locust** was considerably used on sailing boats for the rudder post but on motor boats little is seen of this wood; once in a while a pair of bitts are made of locust. In various parts of the country, other woods are used, but as a rule they do not differ essentially from those mentioned. The **iron bark** on the Pacific Coast is practically the same and is used for the same purpose as the eastern oak, etc.

KEEL CONSTRUCTION

47. As previously stated, the keel is the backbone of the boat and is the main timber upon which the rest of the structure is set up. Its shape and dimensions depend, in a large measure, on the design and size of the boat. In small light runabouts, where the keel does not extend below the bottom of the boat, as in Fig. 40 (*a*), it is called a *plank keel* and is usually made from a wide flat board having enough thickness to insure the stiffness necessary in this part of the boat.

A better form of construction is the *rabbeted keel*, shown in (*b*), where the keel is from one and one-half to two times as thick as the planks composing the hull of the boat. This keel has a rabbet cut in the lower edges to receive the planking, as shown in the figure. The rabbet has the advantage of dispensing with a seam along both sides of the keel and binds the planking more firmly to the keel.

48. In rowboats and some small launches, the keel is made up of two pieces, the lower one set on edge and the upper one laid on top of it, forming a cross-section resembling the letter **T**, as shown in (*c*). The upper piece *a* in this case is called the *keel batten*, as it is a long thin batten of wood continuous from end to end.

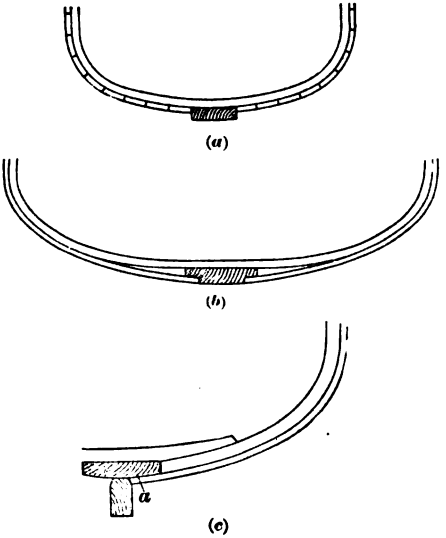


FIG. 40

A very common way of building a keel, particularly in the older type of boats, is to nail the frames on the top of the keel and when they and the floors alongside of them are all in place drive short blocks of oak in tight between the frames and spike them to the top of the keel. These blocks, known as *keel blocks*, overlap the sides of the keel and form a back rabbet for the reception of the plank, Fig. 41.

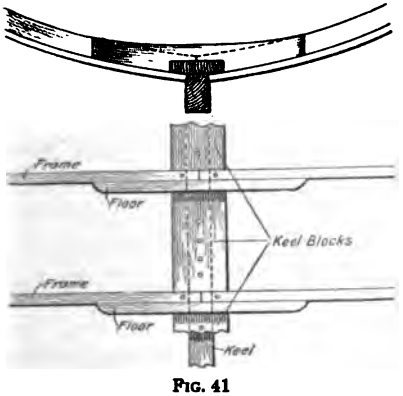


FIG. 41

Formerly keels were built of straight timber, differing only in the angle at which they were slanted or raked, giving more or less drag as the experience of the boat builder dictated. Today there are so many different kinds of craft that all sorts and shapes of keel have had to be evolved. In some cases, a flat plank keel is used and bent to the sweep or curve of the bottom; in others, a log keel is used; and in still others, a combination of both plank keel and log keel is used.

49. Scarfs.—In small boats, there is no difficulty in securing a keel out of one piece of oak or yellow pine; but in large craft it is very often necessary to join two pieces together. The joint thus formed is known as a **scarf**, and may be made in a number of ways, as shown in Fig. 42.

View (*a*) shows a *plain scarf;* the length of a scarf should be not less than four times the depth of the timber and the nib ends should be about one-fifth the depth and cut with a bevel so that when clamped down they make a perfectly snug fit.

View (*b*) shows a *hook scarf;* the hook in the middle of the joint prevents their pulling apart endwise after they are bolted together.

View (*c*) shows a *lock scarf*, which is similar to the hook scarf, except that there is a square hole left at the hook part and the nib ends are cut with an under bevel so that after they are dropped together these ends can be forced snug into the under cut by driving a wedge-shaped oak or locust key into the square hole at the hook.

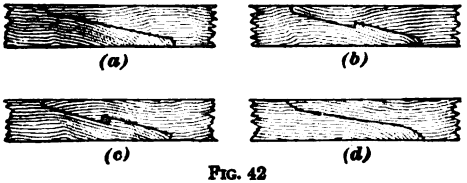


FIG. 42

View (*d*) shows a *Chinese scarf*. Every square saw cut in a timber is more or less of a weak spot where a crack is likely to start; with a Chinese scarf there are no square corners and the strength of the wood is very nicely proportioned throughout the scarf.

50. Keelson.—The keelson is a rather heavy plank that runs fore and aft inside of the boat and on top of the frames, as shown in Fig. 43. It is bolted through to the keel and forms a girder that greatly stiffens the boat's longitudinal structure. Yellow pine is generally used for the keelson, though in some cases builders use oak.

51. Shoe.—A shoe, Fig. 43, is a thin flat batten spiked fast to the under side of a boat's keel, not to take the chafe and wear so much as it is to protect the keel from the destructive wood-boring worm known as *teredo*. One peculiarity about

this worm is that it will not cross a seam, but keeps turning and boring its tunnels in the same piece of wood. The shoe is the part generally attacked first by these destructive worms and

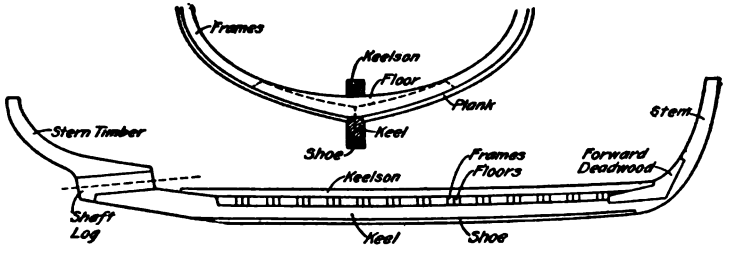


FIG. 43

when badly eaten and honeycombed by holes it is knocked off and a new shoe is put in its place.

52. Stem.—The stem is the timber that forms the outline of the bow and to which the forward ends of the planking are fastened, as illustrated in Fig. 43. In cheaply constructed boats, the rabbet is not cut out of a solid piece but the stem is made of two pieces. The stem proper is the piece between the side planks. The piece bolted on after the ends of the planks have all been trimmed off flush, to bring the bow to a sharp point is called the *false stem*, as shown in Fig. 44 (*a*). The names of the various parts of the stem are shown in (*b*).

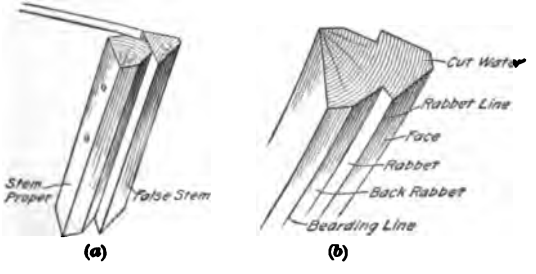


FIG. 44

Most skiffs are built in this manner and some of the launches having straight stems. In boats whose stems are not over 4 feet high the whole stem and forward *dead wood* is cut out of

one hackmatack knee, but where the stem is 6 feet or more high it has to be cut from a piece of oak and backed up by an oak or hackmatack knee bolted to both stem and keel, known as the *forward dead wood* or *stem knee*.

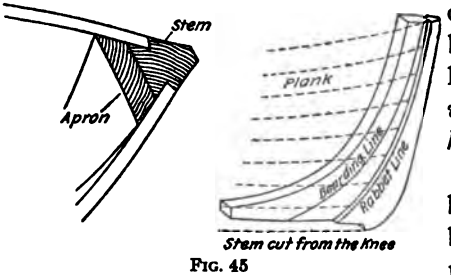


FIG. 45

On boats with bluff bows the stem does not bear very far on the plank ends. To increase the nailing surface at this point, a wide piece, called an *apron*, Fig. 45, is bolted to the after side of the stem, which is fitted snug against the inside of the planking.

STERN CONSTRUCTION

53. The **after dead wood** is generally built up of several pieces of oak cut to suit the shape laid out by the designer. If the boat has a deep keel aft, or a *deep heel*, as the builder would express it, there is, or should be, a vertical stern post *a*, Fig. 46, to hold the after end-grain dead wood in shape. This post also gives a surface of wood through which go the lagscrews on the stuffingbox, or stern bearing *b*, which is usually fitted at this place. The screws should go across the grain of a timber and not into the end grain of it. Some small runabouts have no after dead wood at all; a plank keel is all they carry, with a metal casting bolted on where the shaft comes through.

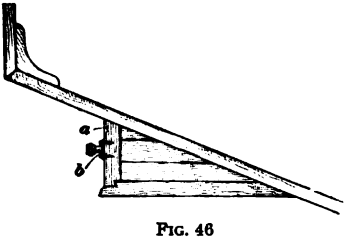


FIG. 46

54. The **shaft log** is that portion of the dead wood through which the propeller shaft goes, as shown in Fig. 43. If it is a twin-screw boat, the shaft logs are the blocks of oaks fitted to the planking to permit holes being bored through for the shaft, which can, by means of stuffingboxes, be made

water-tight. In some boats there is no separate piece of wood that can be called a shaft log, in which case the hole goes right through the dead wood and stern post; in other boats, the shaft log forms one of the several pieces of which the dead wood is built up. Where the dead wood is made thin, the shaft log is sometimes swelled and its edges shaped down even with the rest, as in Fig. 47.

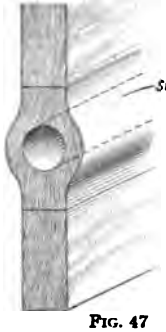


FIG. 47

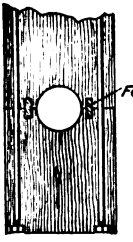


FIG. 48

It is sometimes impossible to bore the shaft hole owing to the length of the shaft log; in that case the log is formed of two pieces with the hole gouged half out of each piece and bolted together. But as such a seam is likely to leak, a slot is sawed in the wood on each side of the shaft hole in each piece and into this a thin strip of soft white pine is fitted to make the seam water-tight. Any water filtering through the joint will cause the pine to swell, rendering the seam water-tight. This strip of pine is known among builders as a *feather* and is shown in Figs. 48 and 49.

On some small runabouts, this system of gouging the shaft hole is employed, but instead of one piece setting on top of the other the dead wood is composed of two thin pieces placed edgewise and clamped and riveted together side by side, as in Fig. 49.

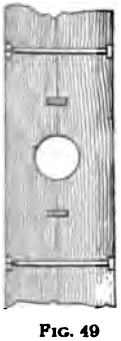


FIG. 49

55. Sleeve.—It is difficult to keep a shaft hole water-tight for any length of time, even with the precautions just described, and the chances are that a check, or crack, may develop in the dead wood right at the shaft hole and cause a leak. For this reason the shaft holes in well-constructed motor boats are lined with a

FIG. 50

lead sleeve, which is fitted through the hole and has its two ends flanged over in a slight recess cut to receive it at each end of the dead wood or shaft log, as is shown in Fig. 50. The edges of this sleeve are tacked securely after a layer of white lead has been placed under the flange.

Some builders take even greater precautions to keep this troublesome part of the boat tight. A brass pipe is fitted to the stern bearing on the outside and the stuffingbox on the inside, making a non-leaking, metal, shaft hole, as shown in Fig. 51.

The difficulty with most small launches is not only that the shaft hole is not lined, but only one bearing, an outside stuffingbox is used, and any leaks that may develop inside the stuffingbox allows the water to flow right into the boat. If the propeller strikes a log bending the shaft slightly, the wobbling reams out the bearing at the stuffingbox and a leak develops. A rope picked up by the propeller often causes the cap on the stuffingbox to unscrew. An outside stuffingbox is, therefore, not very safe. It means going overboard or beaching the boat to get at the stuffingbox to tighten it up. On all boats, the stuffingbox should be placed inside so as to be readily and conveniently accessible.

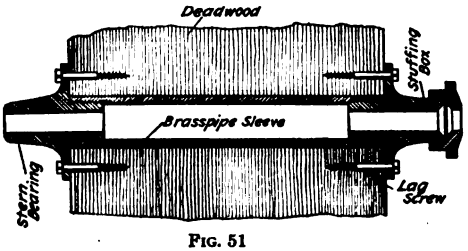


FIG. 51

56. Stern Post.—The stern post is just the opposite to the stem; it is the vertical, or nearly vertical, piece to which the after ends of the planking are fastened on double-ended boats and to which the rudder is hinged in sailboats. Only boats that are deep aft have stern posts; the modern runabout, which is very shallow aft, has none at all. Some with a very short skeg or dead wood have what is similar to a stern post in the short vertical binder on the after end of the skeg, which covers up the end grain of the dead wood.

57. Fashion Timber.—In boats where the stern is carried well out aft beyond the dead wood, the timber that serves as the keel to this part is known as the *stern timber*, or *tail feather*, as it is sometimes called; a more popular name is the **fashion timber**, Fig. 52 (*a*). In some cases, the plank keel is carried through in one continuous piece, as shown in Fig. 52 (*b*) doing away with the fashion timber. Before the advent of the modern motor boat, when all boats were very similar in design, every stick of timber had a standard and well-defined name. For example, the timbers that projected aft of the stern post, carrying the overhand, were known as the *horn*

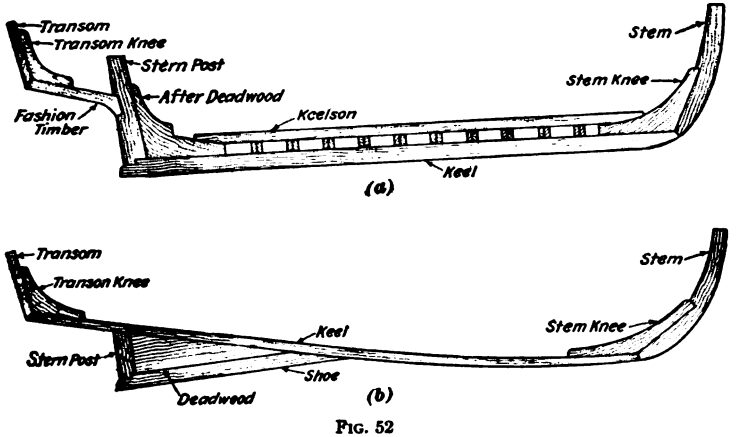


FIG. 52

timbers; but with numberless varieties of yachts now designed there have been evolved some shapes that require pieces of wood far different from the earlier types of boats, with the result that local names have been given to some, such as the case just cited.

58. Transom.—A double-ender or canoe-sterned boat has a stern post and a stern knee to secure it to the fashion timber; but where the stern is square, the end is called the **transom** and the knee of course is the **transom knee**, as in Fig. 52. Some builders put up a rough oak transom to which they fasten the planking and then place a thin quartered-oak or mahogany *false transom*, Fig. 53, as it is called, over the outside of it. The

two pieces should not be fastened right flat together but thin slats of wood, called *furring strips*, should be between them, as in

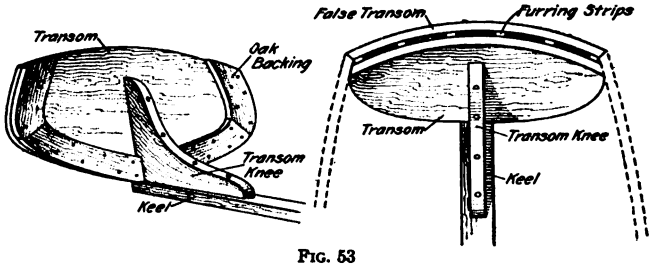


FIG. 53

the figure, to hold one away from the other, thus permitting air to circulate and so prevent dry rot from destroying the woods.

FRAMES

59. The **frames, timbers,** or **ribs,** as some call them, may be fittingly compared with the bones of a fish that radiate from its spinal column. They hold the boat's planking in much the same manner as the fishes bones hold out the skin and scales.

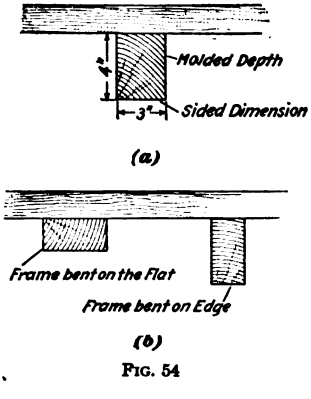


FIG. 54

The distance, or thickness, of a frame between its outer and inner edge is known as its *molded depth*. The width of the frame, its thickness measured fore-and-aft, is the frames *sided width*, or dimension. Referring to Fig. 54 (*a*) these terms are used as follows: The frames are molded 4 inches and sided 3 inches.

A frame that is not square but, say, 2 inches one way and 1 inch the other is said to be *bent on the flat* when the 2-inch face is next to the plank; if it is placed with its 1-inch face next to the plank it is *bent on edge*. Both kinds of frames are shown in (*b*).

The distance between the frames is called the *spacing;* if measured from the center of one frame to the center of the next

it is the *spacing to centers*. If measured between frames it is *in the clear*. There are two kinds of frames used in boat building, the sawed and the steamed.

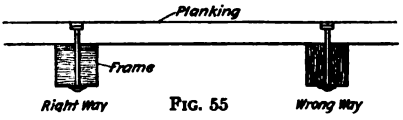


FIG. 55

60. Steam Bent Frames.—Nearly all small-sized boats have steam bent frames. The wood is first sawed into strips, generally square, so that the best side can be selected when it is bent. By putting these strips into an air-tight box and turning steam into it for a short time, they become so soft and pliable that they can be bent into almost any shape without breaking. Oak and elm are the two woods most generally used for bent frames. In localities where crooked oaks are plentiful, sawed frames made from such oaks are still used for the construction of small launches.

The frames should be bent so that the grain of the wood runs fore and aft or in the same direction as the plank runs and not athwartships or across the boat. In the former case the annular layers of the wood lie flat against the planking and the bolts or rivets have a much firmer hold, whereas in the latter case the bolts run between the layers and may cause the frames to split. Fig. 55 shows this more clearly.

61. Sawed Frames.—Any boat whose size requires a frame as heavy as 3 inches square, or larger, generally uses sawed frames on account of the difficulty in bending frames so large. These frames are made up of several pieces, as shown in Fig. 56. The piece *a* is the floor, or *heel*, of the frame; *b* the *futtock;* and *c* the *head*. The butts *d* are never placed opposite each other but are *staggered* so that they alternate first on one side, then on the other. A boat that has a reverse

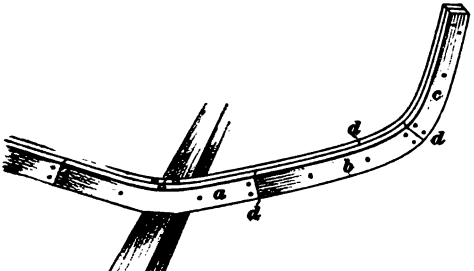


FIG. 56

curve in her frames, and most of them used to have a reverse in the after frames down on the dead wood, sometimes has a combination of a sawed floor *a*, Fig. 57, and a steam bent frame *b* riveted to it.

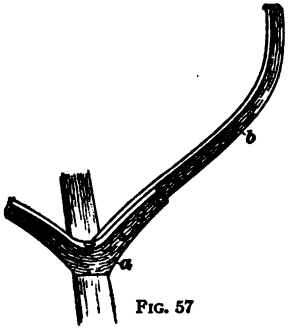


FIG. 57

62. A **tapered frame** is one made narrow at the head or top, and gradually increasing toward the heel where it joins the keel.

63. Split Frame.—When a heavy frame is too stiff to bend and has to be split, as in Fig. 58 (*a*), with a saw down as far as the stubborn part of the bend goes, it is called a **split frame.** Although the fastenings hold both pieces together, such a frame is not so strong as a solid one and is more liable to rot.

64. The **web frame,** Fig. 58 (*b*), is often used opposite that part of the hull in which the engine is to be placed in order to stiffen the structure against the strains and vibration of the motor. Inside of the regular frame and at a suitable distance apart are placed small blocks as shown. A second oak frame is then bent over the blocks and the two are riveted together at each block, forming a wooden truss or web frame.

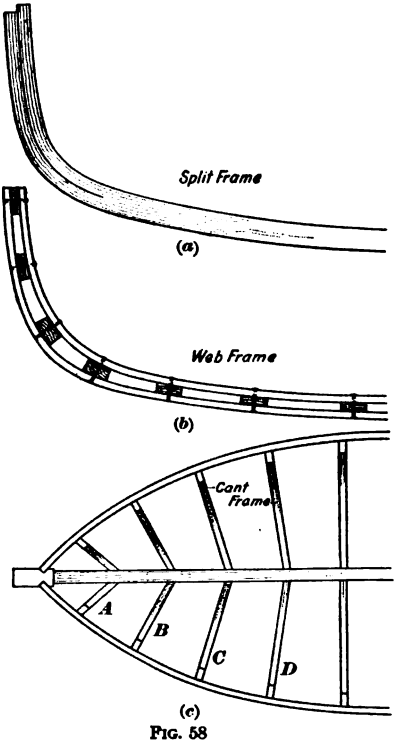


FIG. 58

65. Cant Frame. Sawed frames are always fitted in square across the

boat and their edges beveled to lay flat on the planking, the bevel generally being sawed, or cut, on them before they are set up. Some builders, however, do put up square-edged frames and then *dub* off, or trim them, with an adz, in order to fit the planks on so as to make a perfect joint. To use this method on a boat with very bluff ends would cause too much of the frames to be cut away; therefore, in such boats the frames are fitted in radially in a direction perpendicular to the bend of the planking, as shown at *a*, *b*, *c*, and *d*, Fig. 58 (*c*). Frames placed in this manner are known as **cant frames.**

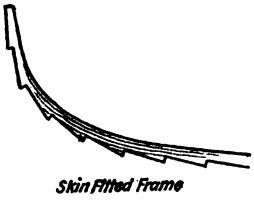


FIG. 59

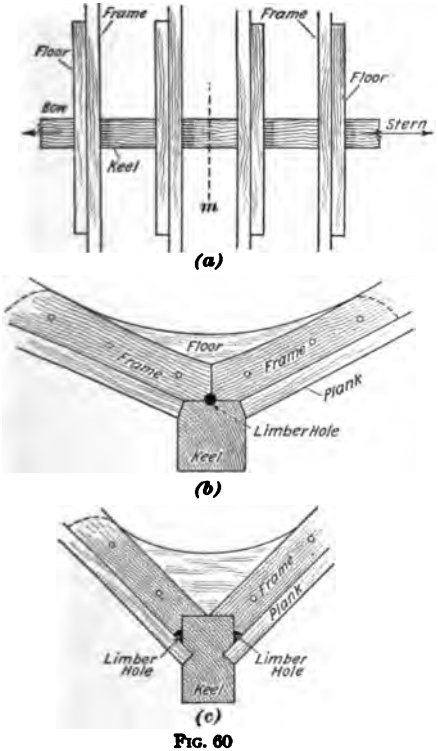


FIG. 60

66. A skin-fitted frame, Fig. 59, is one where the boat is lap-straked or clincher-built and the edge of the frame is sawed so as to fit into each of the sawtooth-like jogs made by this kind of planking.

67. Floors.—In boats with sawed frames, the floors, Fig. 60 (*a*) and (*b*), are made from heavy oak or hackmatack knees. In the midship section, where the bottom of the boat is very flat, they are cut from straight pieces of oak. From the middle of the boat *m* forwards, the floors are fitted on the forward side of the frames and from the amidships to the stern they are fitted aft, as shown in (*a*). This is done so that the

narrowing up of the boat permits the floors to be beveled off and thus greatly increase the nailing surface to which the planking may be fastened. Were they placed on the other side of the frames, the widening of the boat would prevent the plank from even touching the floors. In lightly built launches, the floors are often made from pieces of wood the same size as the frames, this piece being bent across on top of the two frames, where they join at the keel, and riveted to each frame.

68. Limbers are the holes or notches, Fig. 60 (*b*) and (*c*), cut out of the heels of the frames to allow any water that may leak in to flow freely toward the deepest point in the boat's bilge where a pump is generally fitted to discharge the bilge water overboard. Sometimes they are gouges cut in the top of the keel or out of the inside of the plank. To prevent these small holes from getting choked with chips and dirt, a small chain, called a *limber chain*, is run through them ; this chain is pulled back and forth occasionally to clear out the limbers.

69. Clamps.—Before the planking of a boat is begun, the framework should be bound together and stiffened with fore-and-aft pieces of yellow pine, called *stringers* or *clamps*. By being bolted to each frame, the clamps carry the strength of one frame along to the next and so distribute the strains and greatly stiffen the structure. In Fig. 5 these clamps are clearly shown. The upper one under the deck beams is called the *deck clamp;* the one in the turn of the bilge is the *bilge clamp;* and the one just outside of the end of the sawn floors is the *floor clamp*. On account of the ease in which they bend when placed with the flat side down most clamps are made that way and bent in on the flat. But in light racing boats, where every pound of wood tells, these clamps are narrow strips of spruce or yellow pine bent in on edge. Both methods are shown in Fig. 61.

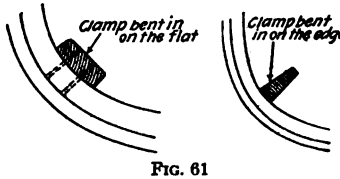


FIG. 61

To further stiffen the deck edge, where the boat takes all the bumps of going up alongside of a dock, another long piece of

yellow pine known as the *shelf* is bent in against the deck clamp. This shelf, shown in Fig. 62, also serves the purpose of an additional support to the deck beams.

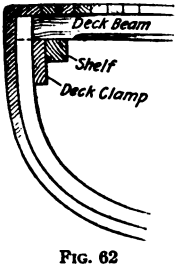


FIG. 62

70. Breast Hook.—The breast hook is the oak or hackmatack knee that is placed inside the point of the bow of a boat on top and fastened to the ends of the deck clamp, Fig. 63. It provides a good holding place for the bolts that bind the bow together. In motor boats, this breast hook is generally covered over and many boat owners do not even know it is there. In rowboats, however, it is generally exposed to view.

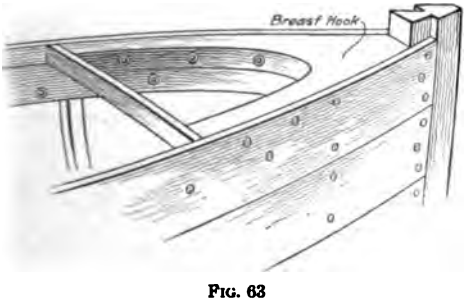


FIG. 63

71. Quarter Knee.—The quarter knees serve the same purpose aft as the breast hook does in the forward part of the boat; they strengthen the corner between the sides and the transom. Any knee that is fitted in horizontally is a *lodge*

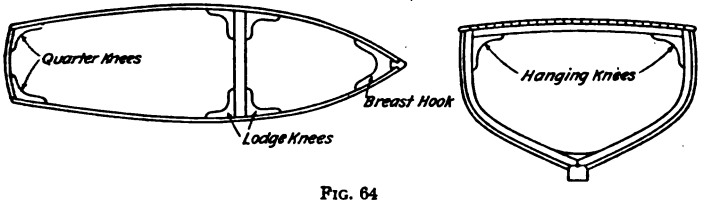


FIG. 64

knee, while those that are set vertically and stiffen the joint where the deck beams join the frames of the boat are *hanging knees*. The different kind of knees are shown in Fig. 64.

PLANKING

72. The planking of a boat is quite an art. A house carpenter can measure the length and width of a roof and tell just how many boards of a certain size it will take to cover it, but a man cannot tell, by measuring a boat, how much lumber it will take unless he has learned by experience how much waste there will be. Every change in a boat's shape makes more or less waste in getting out the planking; while this waste also depends on the character of the lumber at hand with which to do the planking. Some boats require crooked plank to cut to advantage, while others require straight ones.

73. Woods for Planking.—The size of the boat determines in a measure the kind of wood that shall be used for

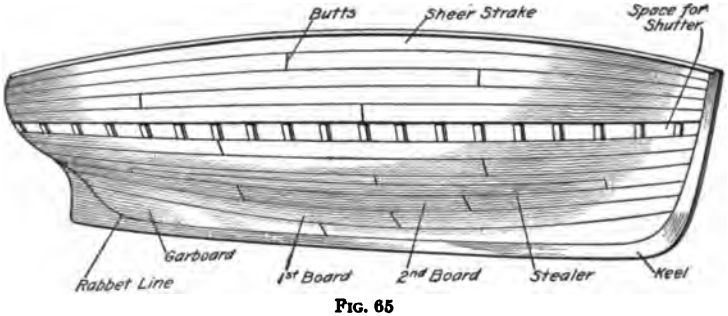


FIG. 65

planking. On most small boats, from 30 to 40 feet long, white cedar is generally used. As cedar runs in market lengths of 12, 14, 16, 18, 24, and sometimes up to 32 feet, it would make too many butts to use this wood for the planking of larger boats. Yellow pine of the long-leaf variety is more suitable for boats over 35 and 40 feet, because it may be procured in very long lengths and is not so expensive as cedar, while being a tougher and stronger wood. Oak is the best wood for the plank next to the keel, known as the *garboard*, followed by a couple of yellow-pine *strakes* as each line of plank is called. The first plank next to the garboard on either side is known as the *first broad strake*, the second the *second broad strake*. The

top plank of the hull proper, not the raised-deck part, but the strake that comes flush on top with the main deck beams, is called the *sheer strake*, as it is the plank whose edge outlines the sheer of the boat.

74. When planking a boat, the work is started alternately from the deck down and from the keel up. The last plank to go on, the one that closes in the hull, is called the *shutter*. The various planks referred to are shown in Fig. 65.

Sometimes a boat is so big around the middle and so small at the ends that to use the same number of planks from end to end would make them come too narrow at the ends. A plank or two are then worked in that do not go all the way to the ends, but merge the two into one; such planks are called *stealers*.

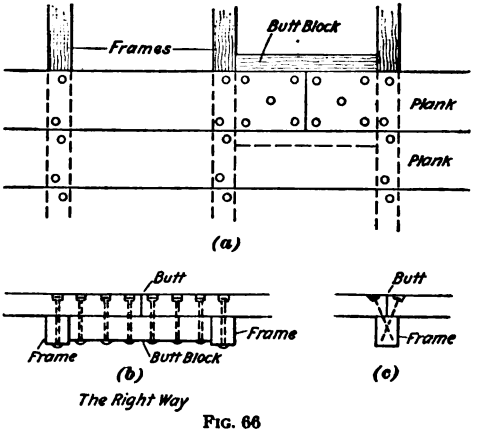


FIG. 66

75. Butts.—A boat of any size with her planking in one piece from end to end is a rarity. Owing to the crooked shapes the planks have to be made it is difficult to get lumber from which they can be so cut. A **butt**, or the joint where the two ends of a plank meet, if made properly is stronger than the board itself, as it is backed inside between the two frames by an oak block called a *butt block* that is about one and one-fourth to one and one-half times as thick as the plank, and is wide enough for its edges to lap over the planks above and below it, as shown in Fig. 66 (*a*) and (*b*). This gives additional strength to the butt. Only an inexperienced builder would try to nail both ends of the planks forming a butt on to one frame, as in (*c*), as such a construction is not only faulty but dangerous.

In some very lightly constructed boats, the planks are halved together and the joint glued and riveted. The lap on the

outside is never allowed to come to a sharp edge, or as boat builders call it a *shim point*, as it will curl and split with the heat of the sun. It is always cut so that it is at least $\frac{1}{8}$ inch thick. The inside, however, may be a shim edge, as shown in Fig. 67.

FIG. 67

76. Carvel Plank.—There are number of ways in which the planking of a boat are joined at their edges so as to make the seams water-tight. The general method in use all over the United States is what is known as the smooth, or **carvel plank,** where the edges lie square one against the other. The inner edges should fit closer than the outer edges to make what is known as a *caulking seam*. The pressure of water then aids in pushing the caulking cotton and putty, with which the seams are filled, into a seam that gets smaller and smaller. But if the seam is a *hollow seam*, as it is called when the seam has a wider opening on the inside than on the outside, the pressure forces the caulking through the seam and causes it to leak. The right and the wrong ways of caulking seams are shown in Fig. 68.

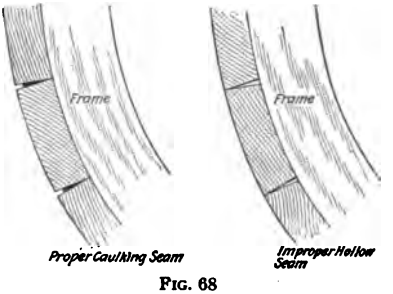


FIG. 68

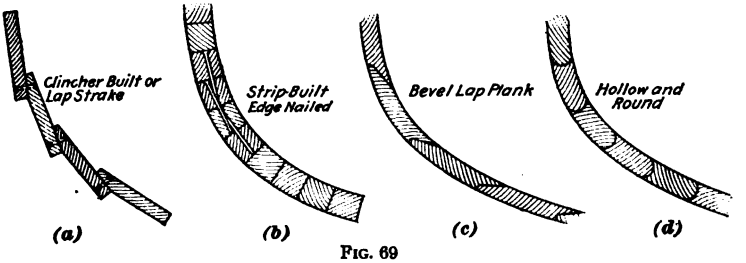


FIG. 69

77. Lap-strake, or clincher built, boats have the planks overlapping each other and the lap riveted together as shown in Fig. 69 (*a*). Such seams do not have to be caulked.

Hollow and round planking, shown in (*d*), is an attempt to make a seam tight without the use of caulking. By forcing the round edge tightly into the hollow of the next plank a water-tight wood-to-wood contact is obtained. This is not a good system to follow, as unless the seams are absolutely perfect and water-tight it is impossible to make them so.

Strip-built boats, shown in (*b*), are boats whose planking is a series of parallel strips nailed edgewise together as well as to the frames.

Bevel-lapped seams, shown in (*c*), are used in light construction, the edges being beveled off acutely and then laid together in glue and varnished.

Halved lap seams, Fig. 70 (*a*), are a modification of the bevel-lap seams and are riveted together in the same manner.

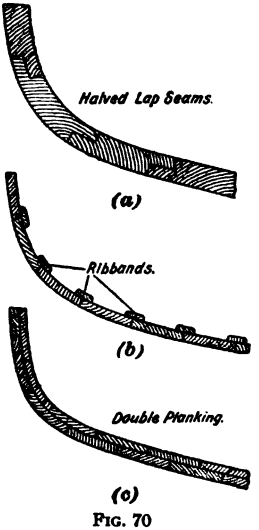


FIG. 70

78. Ribband Carvel Plank.—For more substantial construction and one much used in the lightly constructed hydroplanes of today is the **ribband carvel** shown in Fig. 70 (*b*). It is the same square-edge seam as in the ordinary carvel planked boat, but behind each seam, reinforcing it, is an elm batten to which the edges of both planks are riveted.

79. Double-planked boats have two thicknesses of very thin planking, sometimes with only paint between and sometimes with painted or varnished canvas. This method is illustrated in Fig. 70 (*c*).

Diagonal-planked boats are almost the same as the double-planked, but the inner thickness is laid across diagonally. Sometimes a second diagonal thickness at right angles to the first is laid over the frames and then the third and final thickness of plank is laid fore-and-aft over all. This crossing of the grain makes a very strong sort of veneer construction. Mahogany is generally used for the outside planking of boats built in this way as it is durable and gives a fine, smooth surface.

80. Canvased Hulls.—Canoes and some of the smaller runabouts have canvas stretched tightly over a thin wooden planking. When the pores of the cloth are filled by painting, this material makes a tough smooth skin that will not leak.

DECK CONSTRUCTION

81. Decks are constructed or laid in various ways, the principal ones being shown in Figs. 71 to 74. A **straight laid**

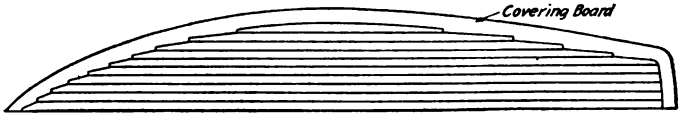


FIG. 71

deck, Fig. 71, is one where the planks run straight fore-and-aft, and the outer ends are nibbed into the oak *covering boards*, *plank sheers*, or *waterways* as they are variously known.

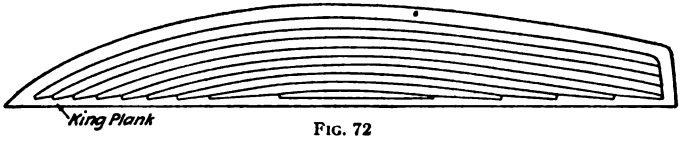


FIG. 72

A **sprung deck,** Fig. 72, is one where each plank is bent so that it follows the curve of the side line of the boat and the ends are then nibbed into the *partner plank*, or *king plank*. Sometimes no partner plank is used, but the ends alternately lap by each other, forming what is called a *herringbone style*, as shown in Fig. 73.

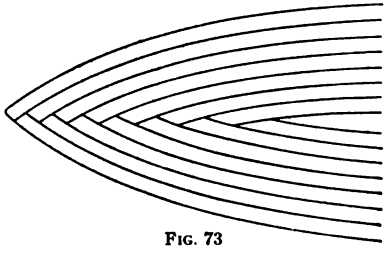


FIG. 73

A **taper-laid, or yacht-laid, deck,** Fig. 74, is one where there are the same number of deck planks at each end as there are in the middle, each plank being worked out to a true taper.

82. Decks should never be flat any more than the roof of a house; they must be built to shed water. But as a pitch roof

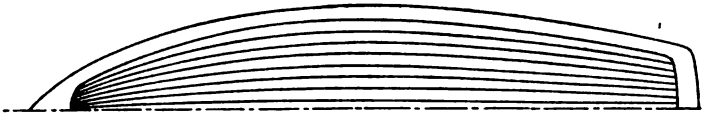


FIG. 74

is hard to walk on, boats' decks are curved from the center line toward the sides. In this way, there is always some level spot to walk on and the deck drains off water readily. The midship part of the curved deck is known as the *crown* and the cabin top should always, to look well, have a little more crown than the deck. The deck and cabin beams are generally cut from oak and all openings, such as the companionway or skylight, are framed with oak *carlines* as the fore-and-aft pieces are called.

83. In ships and large-sized yachts having decks 3 and 4 inches thick there is no difficulty in putting enough oakum and pitch into the seams to keep them water-tight; but, in smaller-sized crafts, where the deck planks are only $1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick, it is not so easy. As a result most small yachts today have canvas-covered decks, canvased cabin tops, and canvas used on everything that acts as a roof. Some few do affect the bright yacht-laid deck of old. The deck planks themselves generally are narrow strips of white pine, free from knots, laid

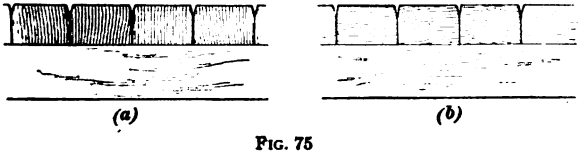


FIG. 75

so that the edge of the grain is up, Fig. 75 (*a*), or *comb grained* as it is called. This wears down even and not in spots, as it would if laid with the flat of the grain up, as shown in (*b*).

84. The **waterways, covering boards, or plank sheers** are generally oak or mahogany, except on racers where to save

weight and still have strength, yellow pine is sometimes used. This plank is sometimes made flush with the deck, as shown in Fig. 76 (*a*). When the deck is covered with canvas, the cloth should be stretched across the covering board and fastened with a molding, as in (*b*). The covering board, however, is often made thicker than the deck itself and coved down, or *beveled* down, to meet the thickness of the deck at its inner edge, as shown in (*c*). It is evident that when the deck is to be covered by canvas wider planks may be used in constructing the deck. But it is well not to use too wide planks on account of shrinkage in the wood that may cause a ridge in the canvas. Before covering the deck with canvas all nail heads should be punched in, and the holes filled with putty. If this is not attended to nail heads will soon eat through the canvas and cause a leaky deck, or roof, as the case may be.

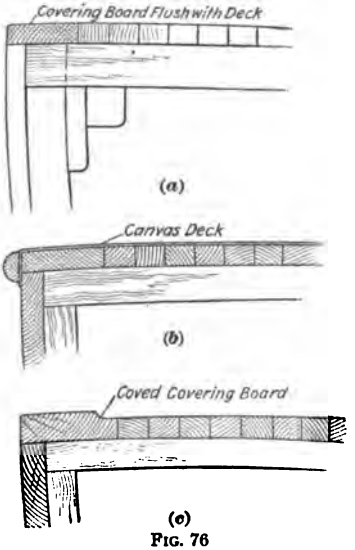


FIG. 76

MOTOR BOATS
(PART 2)

SELECTING A MOTOR BOAT

PRELIMINARY REMARKS

1. Purpose of Boat.—The pleasure a man derives from his motor boat depends, to a great extent, on whether he buys a boat suitable for the use to which he is going to put her. A boat that is built to ride the rough waters of the open sea and that is stoutly housed in, with every window and joint made absolutely water-tight, is a very unsatisfactory craft for a man who wishes to navigate the smooth waters of the rivers and the small lakes of our inland states. Her cabins will be uncomfortable for lack of ventilation and her navigation will be difficult in shallow water on account of the depth of water required to float her, in addition to the inconvenience caused by too high a freeboard. The lake and river motor craft have a much lower freeboard than those intended for deep sea water, and their cabins are built so that they can be opened up on a hot day to cool and ventilate the interior.

2. The difference in the two types mentioned is shown in Fig. 1 (*a*) and (*b*). The deep-sea boat has a freeboard so high as to require a pair of steps to board her, while the deck of river boats can be reached by a step from the seat of a rowboat. River boats, too, having no rise and fall of the water to contend with, such as the tides along the seaboard, can often be moored with their bow run up against the river bank and access given

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to the shore by means of a gang plank. This has lead to widening the deck on the stem head sufficient to handle a gang-plank. Stern wheelers, or *wheelbarrows*, as they are sometimes called, are a type peculiar to and well adapted for use on the western rivers. They float in very shallow water and have nothing on the bottom to foul on submerged tree trunks or sand bars; it is surprising that more western yachtsmen do not have yachts of this kind.

Owing to the wide publicity given the good points of boats built on the dory and whale-boat models, which were primarily built for the roughest kind of sea work along the New England

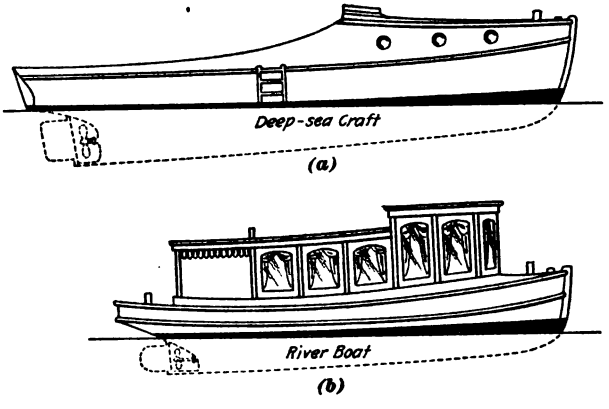

FIG. 1

coast, many boats of these types, using propellers, are found on inland lakes and rivers. Nevertheless, navigating facilities and wind conditions generally prevailing, have had much to do in producing a type of boat best suited for each locality.

3. Advantages of Second-Hand Boats.—It is generally recognized that the first cost of a boat, like any other article, is always the greatest. As soon as a boat has been used it becomes a second-hand one and a reduction in price immediately follows, though as a rule a boat is best found and fitted in her second and third years. No matter how much planning and care were exercised in her outfit, there is always considerable time required to adjust every little thing so that it will be the

handiest. A few months' use of the boat often demonstrates that the initial planning was in some particulars at fault, while a year's use discloses any slight defects in materials; usually all these have been rectified and things that were not thought of at first have been purchased as needed. So the person who buys a boat a year or so old finds a much better fitted craft in many respects than a brand new boat. Such little fittings as shank pointers for stowing the anchors are right at hand, brass has been tacked over the rail and places where some of the gear has started to chafe, and similar improvements have been made where found needed below. It is the hobby of some men of means to build new boats merely for the delight the planning and outfitting gives them. As soon as there is nothing they can change so as to improve, they often tire of the boat, sell it, and build a new one.

4. Buying Through Yacht Brokers.—This tendency on the part of many owners of motor boats is well demonstrated in the lists of yachts the yacht brokers have for sale. As soon as they hear of a new boat being built, the brokers usually approach her owner with a proposition to list the boat on their books for sale. Whether the owner is willing or not, they generally put her down anyway on the principle that every man has his price if the purchaser wants the boat badly enough to pay it.

The business of yacht brokers is in certain respects similar to that of a consulting engineer. The prospective purchaser tells them what kind of a boat he wants, where he proposes to use it, and under what conditions he expects to operate it. The brokers, having on their list boats of all sizes, shapes, and qualities, and being continually busy negotiating between the men who build and the men who buy, are in a position to give valuable advice to the customers and help them select a boat that will best meet the requirement and purse of the buyer. The builder tries to get a good profit, the designer endeavors to produce a boat that, by its appearance, will advertise his work, but the broker's stock in trade lies in giving his customer what he wants; in other words, make him a satisfied customer.

5. If a man intends to select a boat by going around and looking over the fleet at shipyards and yacht clubs in winter, he should take with him some friend who has had experience and whose advice will be of value when making the selection. But a friend's advice sometimes is wrong, for he may have had a very limited experience or he may be biased in certain ways, due to various experiences with his own boat, that have emphasized certain features to the detriment, perhaps, of many other equally important points that have not been impressed on his memory by personal contact.

6. Best Time to Buy a Boat.—As a general rule, the fall is the best time to buy a boat. The season is then over, the long winter months offer no prospects for using the boat for some time, and many owners will sell cheaper at this time than any other so as not to have the expense of wintering the boat and paying storage. Another good time to invest is in the spring, just when every one is in a hurry to get his boat put over; there are always some boats in the fleet that winter in shipyards or on club grounds, whose owners are willing to sell below cost, so that inquiry there often produces a bargain.

POINTS TO BE NOTICED WHEN EXAMINING A MOTOR BOAT

7. Stability.—A boat should never be selected for a certain class of work because of her pretty appearance. Rather, a person should first ascertain that the essential parts of the boat are going to give satisfaction for the conditions under which the boat is to be used. If intended for the accommodation of parties, care must be taken that the boat is a wide, steady craft, and not a *crank affair*, as sailors call a boat that rolls easily. Women and children do not get much comfort when going out in a boat that lops over on one side every time any one changes his seat; people are always glad to get on shore again from such boats.

If the boat is afloat, her *stability*, or steadiness on the water, is easily tested by stepping on one side and seeing whether she tips readily or not. If she is out of water, the shape of the boat

itself will show it, especially to a person who takes a position behind the boat. If the shape of her frames is fairly flat on the bottom, as in Fig. 2 (*a*), the boat is a steady one; if the sides are steep and the boat is narrow for her length as in (*b*), she will have but little stability and will easily upset. The smaller the boat, the more careful one must be to see that her shape is fit for the service for which she is intended.

8. **Behavior of Boat and Engine.**—It is far better to try a boat when it is afloat; therefore, a purchaser should always insist on a trial trip, for at least a short run with its owner, and should watch closely everything he does. It will often be found that a boat that appeals strongly when she is hauled out on land is somewhat of a disappointment when riding on the surface of

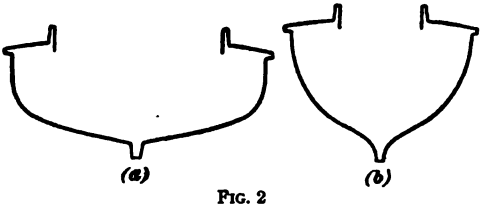

FIG. 2

the water. Boats are very deceptive as to size; they appear large on land but when launched in the water they seem ever so much smaller.

Unless a person has owned several boats he cannot think of everything that is needed on a boat, but a trial will bring up conditions that will remind him of most of the essential things. When on a trial trip, if the gasoline pipe gets choked up it will remind the prospective owner of the advisability of providing means, in this boat's pipe line, for straining the gasoline and catching the sediment. If the motor has to be primed to start, he will see the necessity of having squirt cans aboard, and also have an opportunity to note the ease or inconvenience of priming such a motor. On a trial trip he can see how the motor runs and, by the way it vibrates the boat, whether the engine bed has been well built, if it is in poor condition, and if the motor is securely bolted to its foundations. He can notice, also, if the circulating pump works properly and throws

a good stream of water, or if it is worn and needs new packing. A trial run will test out the ignition system, demonstrate the effectiveness of the clutch and reverse gear, and, in fact, will show about everything a prospective purchaser ought to know about the boat.

9. Appearance of Boat.—A boat must not be judged by the appearance of her paint. Often a bedraggled-looking, dirty boat will prove a far better investment than one resplendent in a new shiny coat of color. If a buyer's mind is settled on the size and type, the next thing is to find a boat of that kind that is well built and in good condition. There is no such thing as a pedigree among boats, but what amounts to the same thing is the name of the firm that built her. Men with long experience in the boating business, however, can tell a great deal about a boat without being told the builder's name.

This is a difficult trait to explain; it takes in so many little betraying points, such as the general appearance of the boat, the style in which the moldings are gotten out, the arrangement of the deck fittings, the abundance or lack of metal deck fittings, and their shape. All these are as a man's handwriting to one who sees many and various boats all the time.

10. The manner in which the hull is painted and varnished, and the fact that the wood under the paint was first properly joinered off and sandpapered so that the paint lays on as smoothly as the surface of a china cup, are other signs by which a certain good builder's work is recognized. Coat after coat of paint may be slapped on in an attempt to hide poor carpenters' work on the planking, but in bright sunshine the shadows thrown across the rounded surface are telltales, indicating whether the seams were properly smoothed down or not; the uneven seams also betray lack of fairness in the shape of the boat.

The fastenings used by reputable firms are made of the best quality of copper and galvanized iron. These firms will not use fittings or wood of inferior quality in the construction of the boats. They buy material in large quantities and keep their wood until it is perfectly seasoned before it is used; any one

who has ever built a boat will realize what an important item this alone is.

11. Condition of Keels.—When examining a motor boat, a person should first stand at one end, say the bow, and sight along the line of the keel or the rabbet line. The foreshortening of the line from this point of view emphasizes an unfairness in the line. Very often a boat built with a straight keel line, particularly an open boat, will show the keel line, as in Fig. 3, arched up in the middle or *hogged*, as sailors say, when a boat is bumped up in the middle and low at the ends. A very flat-bottomed launch is far more apt to hog than a boat with a fair amount of dead rise, as the **V** shape of her sections, Fig. 4 (*a*), along in the middle stiffen and help the keel line hold its shape far better than does a flat-sectioned boat, such as shown in (*b*). This latter boat is so flat that the upward thrust of water against her bottom acts on a wider and, therefore, weaker structure, with the result that the middle stays up while the two narrow ends, bow and stern, having more weight and less buoyancy, or support from the water, sag down. This can be remedied during the winter months when the yacht is hauled out, by spreading the keel blocking well apart so that the middle will have a chance to sag back. If improperly blocked up over winter, that is, if the amidship keel blocks are set up too hard, a boat that was straight may be hogged during the winter season.

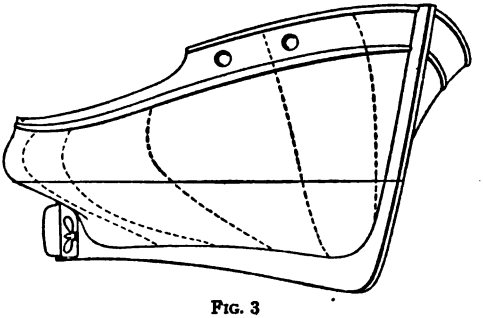

FIG. 3

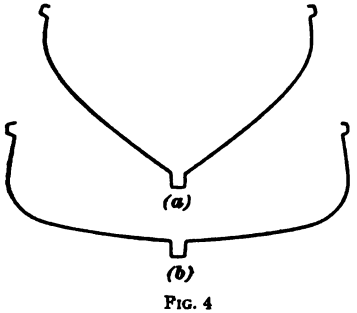

FIG. 4

12. Freedom From Strain.—If the boat is not a straight-keeled boat, but has a *rockered keel*, as it is called when the ends sweep up as shown in Fig. 5 (*a*), absence of fairness in the hull may be harder to detect by the inexperienced buyer. Structurally, a rockered-keel boat is better able to resist hogging strains, as the keel's shape is set, as it were, to resist this, and often there is no unfairness visible in the keel line or rabbet line; but, in this kind of a boat, fairness is more apt to show itself in the curve of the deck edge, as in (*b*). These illustrations have been purposely exaggerated to emphasize the points to be looked out for. Care must be taken, however, that an unfair half-round molding is not mistaken for an unfair side line, as very often this batten has been pushed out of a true

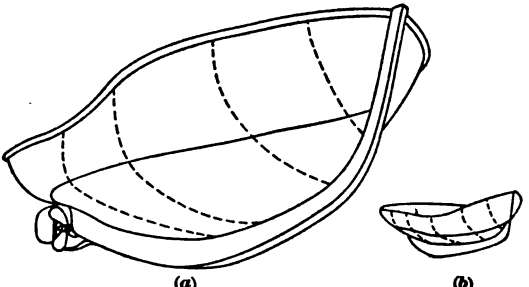

FIG. 5

curve by the owner having jammed a prop under it when the boat was hauled out and then allowed the weight of the boat to settle on this molding, pushing it out of line.

13. There are other ways, however, of finding out to a certainty as to whether the hull is strained or not. One of the best places to examine first is at the garboard seam, where the first plank, the garboard, joins the keel. If hogged, this seam is apt to be fairly tight amidships and pulled open a little at both ends. Evidence of strain shows even more plainly. Up and down the stem, the sagging of the ends pulls the under edge of each plank back and pushes the upper edge forwards, as shown in Fig. 6 (*a*).

If the hull, instead of sagging at the ends, has sagged down in the middle, she is said to be *sagged*. Some long, thin, lightly

built racers show a very pronounced sag right where all the weight of her motors comes. A boat that bends down in the middle in this manner strains her planking so that the lower edges of her planks protrude forwards, as shown in (*b*). Boats that strain in this manner generally show it by a roughened seam in the planking along the amidships portion of the hull; but the splitting of the putty, such as takes place with every new boat when the dry wood of which it is built swells up after the boat is launched, must not be mistaken for this fault.

14. Swelling of Wood.—The swelling of the planks has a tendency to squeeze the putty out along each seam, causing the paint to break into rough ridges; this happens with nearly

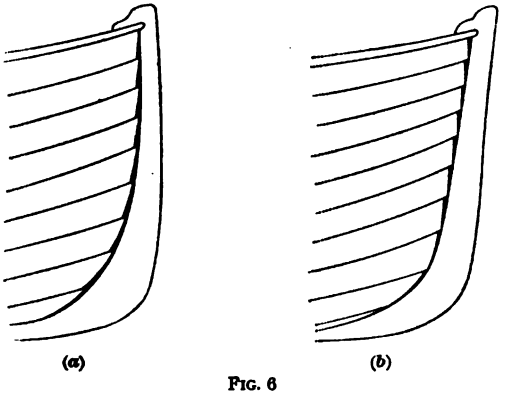

FIG. 6

every new boat, more in some cases than in others, due to the dryness of the wood of which the boat is built. Some of the best builders guard against this swelling by sponging the planking with hot water before they put on the paint, as sponging makes the wood swell all it should; then when dry the boat is finished all over again. When boats treated in this way are launched, they swell again but do not roughen up their seams nearly so much as a boat not sponged. Other builders use the boat a couple of weeks and let all the seams swell and split the putty; they then haul it out and refinish it good for the summer. Some builders finish the seams of their new boats with each seam showing slightly hollow, the putty being below

the surface of the wood, but this does not prevent its cracking as the putty is squeezed out.

Boats planked with yellow pine often have to be put overboard in shallow water and allowed to lay, with the tide wetting the plank thoroughly, to swell the seams tight before the boat is again hauled out, the surface of the plank being allowed to dry a day and then painted; this is because the wood shrinks so during a winter's storage. If the seams are caulked every time hard enough to make them tight when the boat is first put overboard, the swelling of the planking will draw the planks from their fastenings, or she would *sprawl her planks*, as boat builders say.

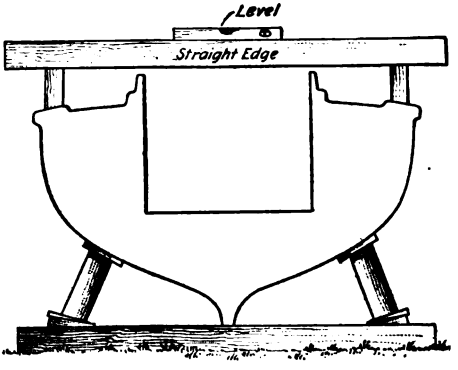

FIG. 7

15. Fairness of Hull.—Another way of seeing if a boat is fair, is to take a position first at one end of the boat and then the other, and observing whether the ends are plumb up and down. As the boat may be listed a little toward one side or the other, this may be difficult to do, but in such a case it is advisable to block her up in a level position. To do this, a straight-edge and spirit level should be laid square across from side to side amidships, as shown in Fig. 7. When the boat is set level, a plumb-bob is dropped at the bow and the stern to see if both ends are plumb.

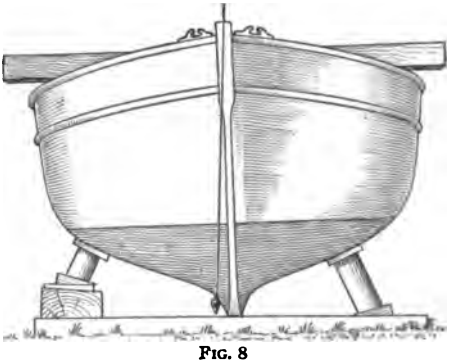
FIG. 8

Some boats have quite a twist to their stem or stern. This may be due to strains after the boat was built, or to the fact that the frame was not properly braced when she was being built, thus causing a lop-sided boat, as shown in Fig. 8. Sometimes the stem will be twisted to one side and the stern to the other. Such a boat it is well to leave alone; she is incurable.

16. No matter whether the boat is large or small, if it is desired to find out if she is built true and fair, a chalk line should be stretched from the exact center of her stem to a point over the center mark of her stern, as in Fig. 9 (*a*). When sure the boat is set up level and plumb, a plumb-line should be dropped through the companionway, or any other opening

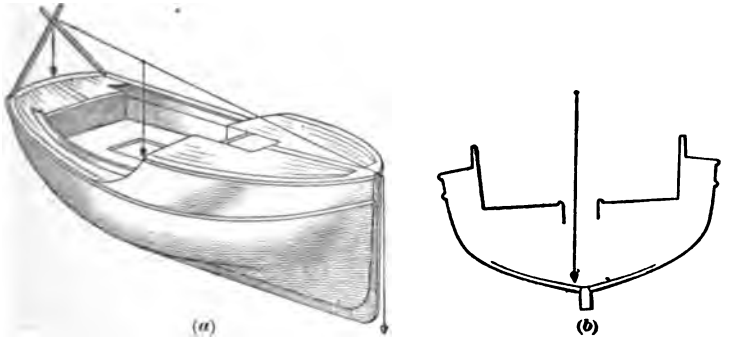

FIG. 9

somewhere along the longitudinal midship line, where the plumb-bob can go through to the bottom of the boat inside to see if it lands in the center of the top of the keel. If the bob falls to one side, as shown in (*b*), and the boat is properly blocked up, the whole boat is twisted.

17. Effect of Exposure to Sun.—A boat that has laid for a long time with one side continually exposed to the sun, the other in the shadow, will show the putty all roughened up along the seams on the side exposed to the sun. This condition should not be mistaken for strains due to structural weaknesses. The sun's heat exerts a powerful action on wood, and in boats where the wood is subjected to alternate wetting and drying,

this is compensated for by not allowing any one piece to be very wide. Some boat owners think it an advantage to have planks 8 and 10 inches wide, and point with pride to the fact that their boats have so few seams to leak. This, however, is of no advantage, as the shrinkage and swelling of these wide planks cause the seams to leak. A better construction is where the seams are not over 6 inches apart on the top sides, at least. Near the keel and under the bottom of the boat, which is always wet, wider planks are permissible and are generally used. The garboard strake, or the plank on each side next to the keel, is, for this reason, much wider than planks above the water-line. Not only are they made broad, but, in the best class of construction, they are generally made thicker at the same time, so that

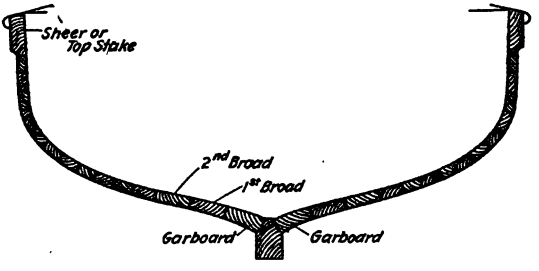

FIG. 10

they taper in thickness, as shown in Fig. 10. This tapering was the universal custom in old-time ship building, but with the cheapening in product the small launches of today generally have the same thickness of planking from keel to sheer strake.

18. Conditions of Planking.—In some poorly constructed boats, the builders do not even take the trouble to hollow and round the planking where it goes over the sharp turn of the bilge. It requires a little thicker plank to hollow out the inside surface of the plank so that is will snugly fit on the face of the frame, as in Fig. 11 (*a*), but it makes a stronger job than where, through poor workmanship, the plank has been put on flat, as shown in (*b*). If the planking is put on as in (*b*), the fact may be discovered by examining the inside of the hull, when it is left unceiled, though most men who do this slovenly

kind of work generally take pains not to expose it by ceiling up the inside where it would show.

19. Rot is the greatest defect to be looked out for when selecting a boat that has been used for some time. It is caused by a general decay of the wood due to age, to the heat and sweat produced by an unventilated interior, and to sap. Rot due to age cannot be prevented; it is to be expected. But rot due to the other two causes is the fault of the men who, either through ignorance or carelessness, permit such a condition. For example, in the case of a handsome 60-foot motor boat that had to have her forward plank ends taken out and new planks fitted on both sides from her stem aft, 10 or 12 feet, so as to shift the butts properly, it was found that the wood taken out crumbled like mold when stepped upon. This yacht had a

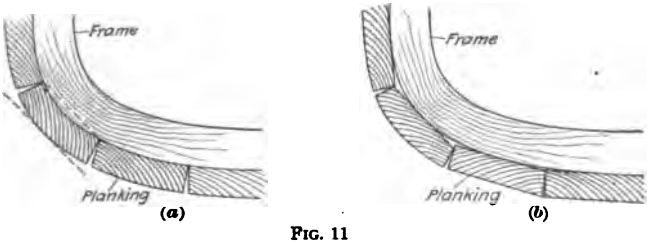

FIG. 11

built-in chain locker that was so tightly ceiled up that every bit of moisture brought into it by the wet anchor chains and wet rope cables, simply steamed and sweat the life out of the wood with the hot summer's sun heating it up. Also, amidships of this same boat, where the planks are generally needed the widest, the builder had cut out the plank so that some of the sap on the edges was left on the planking. When the foregoing repairs were made, it was found that all of this sap had turned to so much rotten punk, so that a man could pick it out with his fingers. This is what happens every time where planks with sap, indicated by the blue-looking wood on the edge of the boards, are used.

20. To find out if there are any sappy edges, when inspecting a boat that is covered with paint, take a pen knife and jab

it into the edge of the planks, also in the extreme ends, where sweating inside may have rotted the plank. The middle usually is the best part of the plank. The planks should also be tested along the water-line or about 3 or 4 inches above it, where the wood has been alternately wet and dry. Another place to look for rot is underneath where any tanks may be fitted inside the boat and where the ventilation is poor. It is to ward against this dry rot that experienced yachtsmen fit ventilators at both ends, so as to carry off the heat generated by the hot sun beating down on the deck and baking the air inside. Many a sailing yacht has had to have her entire aft overhang replanked, due to rot, when the rest of the plank, better ventilated, was still sound.

21. Riveting.—The fastenings, if copper rivets, often show up this poor construction by appearing to be loose under

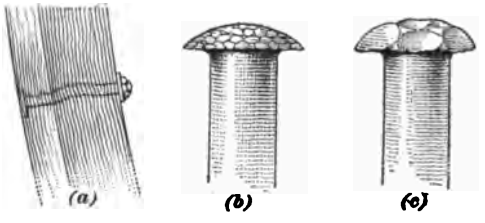

FIG. 12

the burrs when they are riveted on the inside face of the frame. Lapstrake boats show when they are getting old and leaky, due to the wood becoming soft and punky, in the same way. One can put the point of a knife blade under the burrs.

Another reason for these burrs being loose on the face of the frame is poor riveting. A copper bolt or nail is supposed to be tapped just hard enough to expand and curl over on to the little copper washer, called the *burr*, in order to prevent the burr's slipping off, and a few extra taps cause the bolt or nail to curl over and force the burr on so as to pull both surfaces of the wood tightly together. Some poor mechanics, in a hurry to do the job, try to rivet the bolt or nail with three or four heavy drives of the hammer. The usual result is that the heavy blows buckle, or bend, the soft copper nail or bolt in the wood, as in Fig. 12,

(*a*), crushing the burr so that it looks as if it were riveted down. When the strain comes on a nail so buckled, it straightens and the plank is loose, causing a leak in a lap strake boat, and a seam that works and breaks its putty in a smooth planked boat. The character of the riveting may generally be told by the appearance of the head of the bolt; if it is produced by a number of light taps, it will have the form shown in (*b*), but if it is produced by three or four hard blows it will appear as shown in (*c*).

22. Condition of Keel.—The oak keel should be carefully inspected, for while it may not rot, being wholly submerged most of the time, it may have been attacked by the teredo. When this worm starts in a keel it bores back and forth until the wood resembles a sponge. The hole through which the teredo enters the wood is a mere pin point, but a leaky boat is often the result. Shallow water, heated by the sun, seems to be the favorite breeding ground for the teredo, and in southern waters motor boats generally have copper-sheathed bottoms to resist the teredo.

23. Cabin Strains.—Many prospective buyers act as though they thought that a boat is one piece of cast iron instead of being made of hundreds of small pieces; consequently, they fail to realize that the strength of a boat depends on the manner in which these pieces are put together. Many boats that are strong enough to be first-class boats afloat are not strong enough to be left carelessly blocked up when hauled out and all the weight concentrated along the keel. For that reason, it is hardly fair to condemn a boat that is inspected as she lies hauled out in a yard, because the doors stick and bind; when water born, and the strain is more evenly distributed upon her hull, every door and locker may open and close perfectly; but, at the same time, such an inspection will show whether the cabinetwork on the deck has pulled apart or whether it has held together as built. The seam where her deck and covering board meet should be examined, to see if it has strained apart any, or if the seam has an even width all along. The seam where the cabin joins the deck should also be examined; in case it is rotted, one may be able to shove the blade of a knife under it. This, and all other deck openings, should be built so they set on to a

rabbeted *oak sill piece*, as it is called, like Fig. 13 (*a*). Then the solid wooden edge *A* on the inner side of the cabin house, forms a solid water-tight joint, a *back rabbet*, as it is called, which cannot be had in a deck house that is planted *flat footed* on to

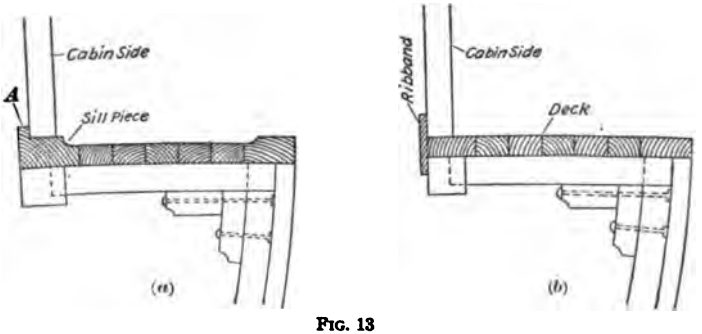

FIG. 13

the deck planks as in (*b*). When constructed in the latter manner, the seam is generally covered on the inside by a flat ribband that hides the construction, but does not prevent the leak that sooner or later is almost sure to find its way through at this point, unless the deck is covered with canvas and the edges under the cabin sides are turned up, as shown in Fig. 14.

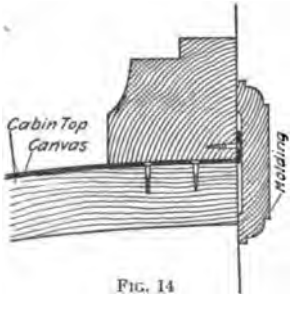

FIG. 14

24. Upper Works.—Inexperienced persons generally pass lightly over the inspection of the upper works of a launch, as if the hull, proper, were the only part worthy of any consideration; but any deck house that is leaky is as much of a discomfort as a hull that leaks; in fact, more so. Therefore, a prospective buyer should look around the lower corners of the windows to see if there is any discoloration, showing that water has leaked in. Around the skylight frames and companionways, also, are places to look for defects of this nature. Few builders today use the bright, or varnished, wooden cabin top; nearly all cover the cabin tops with canvas, which afterwards is

painted. This is the one sure way of having a dry roof; it is around the openings, then, where leaks are to be looked for.

The canvas should not only be laid first, so that it goes under the skylight hatch frame or under the companionway runway, but it should be turned up, as in Fig. 14, to prevent water leaking through the seam; the raw edge of the canvas should then be covered with some style of flat molding, as shown. If the canvas is turned down, there is nothing to prevent the water flowing in if the molding over it does not make a perfect joint.

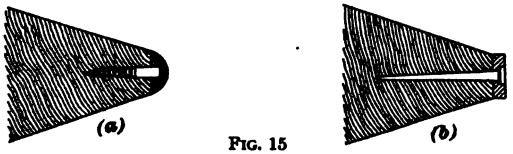

FIG. 15

25. Hardware Fittings.—Outside of the structure of the hull and deck houses, the hardware fittings are next in importance when inspecting a boat. It is here one can see whether the boat is well built or not. Boats that have a well-constructed hull are often fitted with shoddy, cheap ironwork, such as stem bands and skegs made of iron. If the boat is to be used in fresh water, these fittings can be kept in good order for years, by painting, but for use in salt water galvanic action soon corrodes the iron. To use both iron and brass is absolutely wrong, as the iron will rust in less than a year; brass, or bronze, is the only metal to use for salt water fittings.

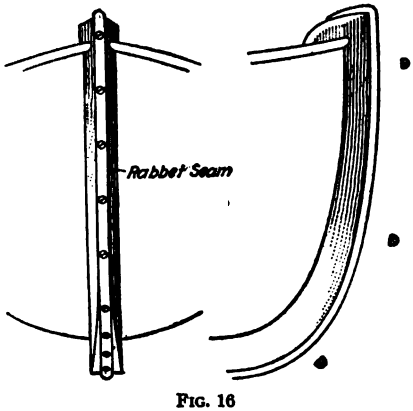

FIG. 16

26. In the case of the stem band, which is put on to prevent the sharp wooden edge from being dented and splintered, a neat half-round strip of brass as in Fig. 15 (*a*), secured by screws,

is far better than a flat piece of iron band nailed to the stem, as shown in (*b*). A half-round stem band used on a boat is an evidence of good care used by her builders. But a band of the same width, down to the round of the forefoot below where the stem widens out to the width of the keel, is not the proper thing; it only covers part of the stem, as shown in Fig. 16. A much neater finish is had by using a brass casting that has been especially made and is widened out to cover the full width of the stem and keel at the forefoot. Such a stem band, shown in Fig. 17, will fit the wooden stem snugly and prevent unnecessary wear in a part of the boat most exposed to chafing.

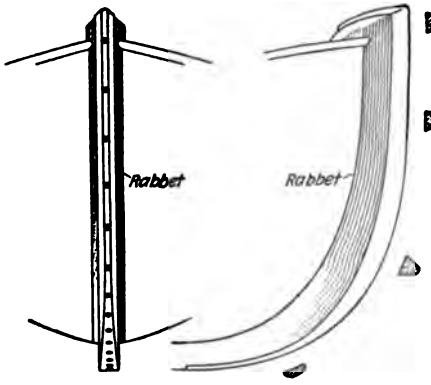

FIG. 17

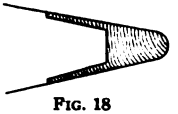

FIG. 18

Cross-sections of this stem, at different places in its length, are shown at the right of the figure. In some well-made boats this form is improved on by casting a lug on each edge of the stem so the wooden stem fits right into the inside of the stem band; Fig. 18 shows a cross-section of such a stem band. The modern racer has a stem band something like this, only instead of being cast, it is made of two pieces of thin brass plate cut to the shape of the stem and let in flush with the surface of the plank. The edges are then ground to a sharp point and soldered together, after which they are fastened to the planking by screws along the inner edges, as shown in Fig. 19.

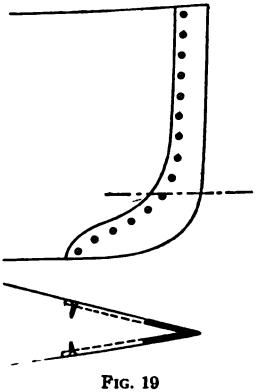

FIG. 19

27. Form of Skeg.—In many motor boats the skeg is used as the main support of the rudder post, and for this reason it should be given a close examination when looking over the boat. As previously explained, the skeg also acts as a guard to protect the propeller from striking obstructions, and from coming in contact with the bottom. In cheaply built boats, the skeg is usually made of a flat piece of metal bolted to the under side

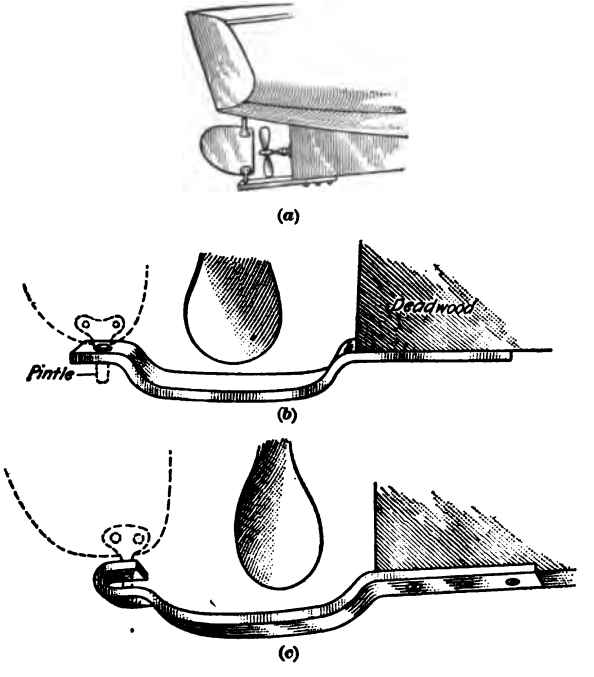

FIG. 20

of the keel, as in Fig. 20 (*a*), and allowed to extend aft far enough to reach the lower *pintle*, as the pivot on which the rudder turns is called.

If such a skeg does not clear the propeller it is bent with a kink, as shown in (*b*). The boltheads, the forward edge of the skeg, and the pintle of the rudder protruding below the line of the keel, are liable to catch on things; to prevent this the forward end of the skeg should be fitted in flush with keel. The

screws should have their heads countersunk, and the after end of the skeg should be folded over, as in (*c*). This arrangement will not only hold the rudder firmly, but the under part of the skeg will serve as a support to the rudder. As the flat surface dragging through the water, bent in this way, is a resistance, the skeg is sometimes given a twist, as in Fig. 21, to make it cut edgewise through the water.

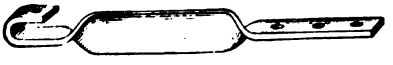

FIG. 21

28. Sometimes the skegs have to reach so far aft that they are hardly able to hold their own weight. To find out if such is the case, the skeg should be given a light downward push with the foot to see if it is firm and solid. To reinforce and straighten the skeg, an upright bolt or bar should be fitted from the hull down and bolted to the skeg just forward of the rudder, as shown in Fig. 22. The proper way in which to construct a skeg on a boat is to have one specially cast, as shown in Fig. 23. Such a skeg, when fitted to conform with the shape and dimensions of the keel, unless smashed by hitting on rocks, will last as long as the boat and give no trouble. It adds greatly to the appearance of the boat when hauled out and is well worth what little extra it may cost over the makeshift kind, which is apt to give trouble. Where extra strength is needed, the skeg can be made and tapered off like a tree trunk, in proportion to the strain it has to bear. It is needless to state that every propeller should be protected by a skeg.

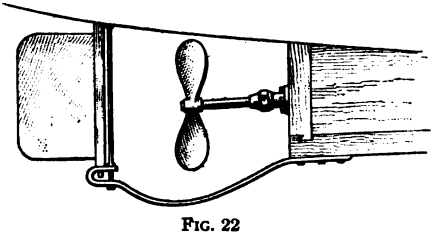

FIG. 22

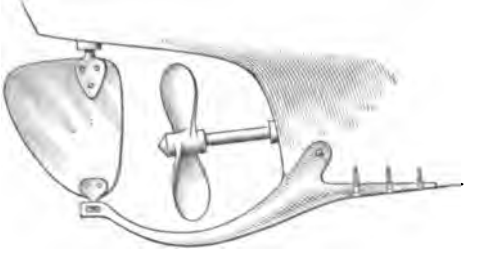

FIG. 23

29. Rudders and Steering Gear.—The rudder is one of the most vital parts of any craft, whether it is a motor, steam, or sail boat; yet when examining a number of boats, one may see many curious appendages attached to the stern to serve as rudders. To make sure that the steering gear of a boat is in good condition, the steering wheel should be tried, to see if the rudder responds readily or if it stands still until the wheel is turned half way around. Through the neglect of the owners or the operators, many boats have what is known as *lost motion* in their steering gear; which means that the rudder does not respond readily to the turn of the wheel. The high-speed hydroplanes have done much to perfect the steering apparatus on small boats; on account of their speed, perfect control and quick response to the steering wheel is an absolute requirement.

30. Hydroplanes use flexible, bronze or steel, wire wheel ropes; and where the rope rounds a corner, there are sheaves of large diameter having a score in the sheave that just

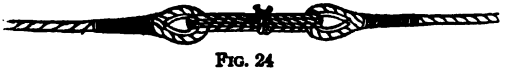

FIG. 24

fits the rope. A score that is too big permits the strands of the rope to flatten down, which is apt to break them, but where the rope preserves its round shape it retains its strength. At a suitable place along the tiller rope, some means of taking up the slack of the ropes should be provided. In some cases, this is accomplished by having two thimbles spliced into the tiller ropes and lacing the two together, as in Fig. 24. This kind of a take-up can be made in any desired length. Turnbuckles are also used for this purpose, though they are limited in their take-up to the length of their screws.

If the boat examined has a turnbuckle, care must be taken that it is easy to get at, to tighten when necessary, and that there is some means of locking the turnbuckle, or the ropes will untwist themselves and slacken the tiller rope, as in the case of a plain turnbuckle shown in Fig. 25 (*a*). This is accomplished by locknuts as in (*b*). Another arrangement, shown in (*c*), is by putting cotter pins through small holes in the ends of the

threaded screws so the head and point of the cotter pin in the slots of the turnbuckle prevent its untwisting.

Few builders take the trouble nowadays to splice the ends of the wire tiller ropes; they use some form of a wire-rope clamp,

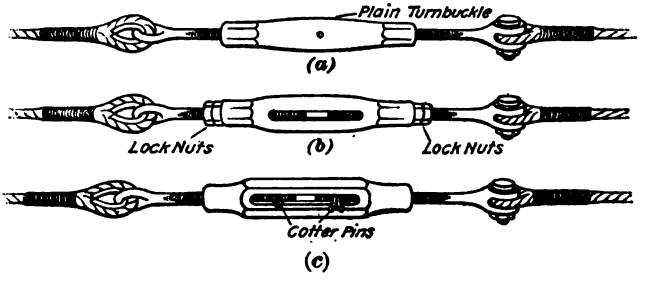

FIG. 25

of which there are various styles on the market. When the tiller rope is made of hemp or manila, the arrangement with spliced thimbles is preferable, while a turnbuckle is more suitable for wire rope.

CARE OF A MOTOR BOAT

FITTING OUT A MOTOR BOAT

PAINTING OF HULL

31. After a boat has been selected, but before it is launched, the hull, and especially the under-water portion of it, should be well caulked, puttied, and painted. It is far more economical to paint and varnish everything that needs it, when the boat is on dry land, before she is put afloat, because after launching there are so many other important things that require attention. The outboard portion of the hull, in particular, cannot be given the same proper attention after launching as when the boat is out of water.

32. In fresh water, any good plain flat or enamel paint will last some time; but in salty water a slime is formed in a few

weeks on which marine growth and barnacles attach themselves and tend to reduce the speed of the boat if not scraped off. Antifouling paints have a certain amount of copper or other ingredients that are supposed to prevent this growth forming on the wetted surface of a boat. Of these paints, there are several brands, some lasting better than others in various localities. It is good policy to apply the kind of antifouling paint used by local boatmen, as their experience is a good guide. Warm shallow water seems to be the conditions where a boat's bottom fouls the quickest.

33. Paint Mixture.—If the boatman desires to mix up his own copper paint, he can use with confidence the following recipe: Red lead, 2 pounds; copper bronze (powder), ½ pound; arsenic, ½ pound; Paris blue, ½ pound; chrome yellow, ½ pound; patent dryer, 2 pints; linseed oil, 2 pints; copal varnish, 2 pints. These ingredients should be thoroughly mixed together with the paddle and thinned to brushing consistency by adding varnish. It dries with a good gloss and of a neat reddish copper shade, is durable and comparatively inexpensive to mix up.

The composition paint should be applied after the finishing coat of white is dry. To prevent the heavy minerals from settling to the bottom of the paint pot, copper paint must be stirred at frequent intervals as the work of painting proceeds, and the paint must be well brushed out.

34. Method of Painting the Hull.—Any one who has ever tried to paint the top sides of a boat when it is afloat knows how difficult, almost impossible in fact, it is to paint a straight line where the white paint meets the red or green copper antifouling paint of the bottom. If the boat to be fitted out is an old one, the upper part of the boat should always be painted first and care taken that the wood is dry, the surface well smoothed with sandpaper, and all seams and holes puttied before the paint is applied. No attempt should be made to paint over places where any grease has been daubed on until all traces of the grease have been removed; otherwise, the paint will soon peel off.

By painting the bottom of the boat last, the brush used for the darker bottom paint will cover any places where the white may

have run a little, and at the same time make it possible to draw the brush along, making a clean sharp line where the two colors meet. By making this a rule any drops of paint that run from the brush will not show on paint of the same color and may be wiped off with the brush, so that it all lies in a smooth coat. The right way to paint a water-line is shown in the upper half of Fig. 26; and the wrong way, in the lower half.

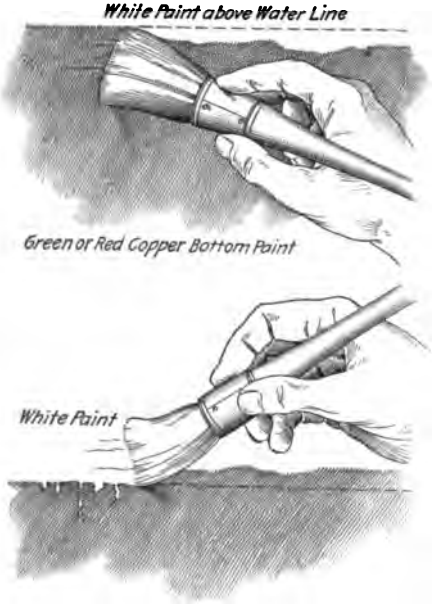

FIG. 26

35. Marking a Water-Line.—A painted water-line that is not straight, as in Fig. 27 (*a*), spoils the appearance of a boat, while a straight, clean-cut edge where the paints meet, as in (*b*), always looks nice. To paint the water-line before the boat has been put afloat, it is neces-

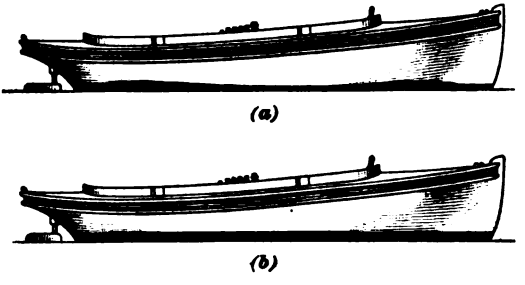

FIG. 27

sary to block up the boat true and construct an artificial level at a height corresponding to the actual water-level on the boat

by nailing a straightedge horizontally across each end at the height desired. By sighting, so that these two are always in the same plane, a person with a pencil can mark points at which this plane touches the side of the boat.

36. A better way even than this is to use the two cross-sticks, leveling them with a spirit level, after the launch has been set up perfectly true, as determined by a plumb-bob hung down in front of the stem, or by a straightedge, laid square across the boat from gunwale to gunwale. These two sticks should be braced by uprights driven into the ground, and also by slanting braces, as shown in Figs. 28 and 29. After tying one end of a string to the forward crosspiece, about the width of the boat out from the center, and pulling it tightly enough to prevent any sag, if the string is moved along the upper edge of the stick at the other end it is easy to mark a level, represented by the cross-sticks, at any part fore and aft on the hull. At the point where the string first touches the hull, a small brad should be

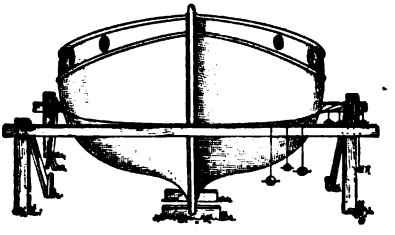

FIG. 28

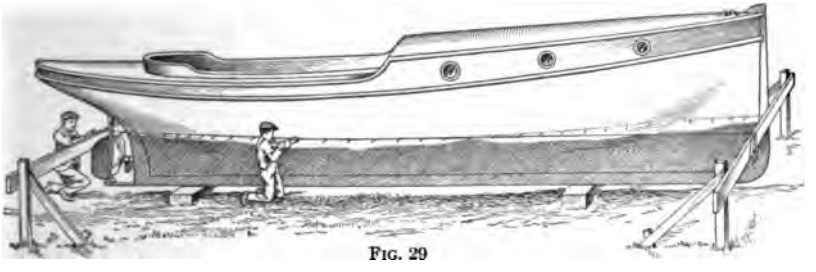

FIG. 29

driven in just below the string; a foot aft of that another, and so on at intervals; one man moving the string in toward the middle of the boat to locate the height of the water-line and another driving the brads, which prevent the string from slipping down. Fig. 29, which is a side view of the boat, shows this clearly. Going around the sharp curve under the slanting

stern, the brads will have to be driven every 6 inches or less, to get a true curve. By reversing the operation, the forward end of the water-line can be marked out in the same way.

37. If, for any reason, the launch is not on even keel, as some persons will not move their launch for fear of her falling over, the two crosspieces can be tilted to suit the angle of the hull, as shown in Fig. 30. If this is not done and the water line is struck in from level cross-guides, the line will be high on one side and low on the other.

To find how much to tilt the crosspieces, a string should be tied along each side so that it just touches the boat amidship; then measuring down from the deck, the sticks should be tilted until the lines measure the same each side; the braces should then be nailed fast and the line struck in as before.

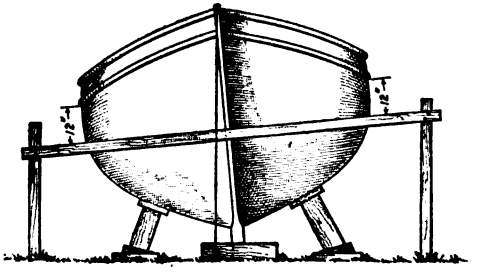

FIG. 30

38. To draw a continuous line between the marks so that the paint line will be fair, a thin batten may be tacked fast so that its upper edge just touches the line of brads. This batten need not be very narrow, as long as it is thin enough to bend along the water-line; in fact, it will give a truer line if it is a thin piece of wainscoting, say, $\frac{3}{8}$ inch thick and about $2\frac{1}{2}$ to 3 inches wide, but the knack of using it is this: Inexperienced persons will try to nail this flat against the hull, with the result that the ends of the batten will turn upwards. This can be avoided by holding the batten so that its lower and upper edges are in the same vertical plane, and then bending the batten so that its upper edge just touches the line of brads, as in Fig. 31. Thin nails may then be driven, slanting upwards through this edge, as shown, to hold the batten in place. It will then bend around in a level plane as required. A pencil mark will soon be lost, so it is customary to scratch the line in with the

point of an awl so that it can be found again, even after the boat has been painted.

39. Use of Varnish.—Decks, coamings, and sometimes a good part of the interior work, are generally varnished. In general, there are two kinds of varnishes, the interior varnish, which will do very well for the interior woodwork of an enclosed cabin, and *spar varnish*, as that used for exterior work is called. A varnish that will not only withstand the heat and cold, wet and dry, but also the bending to which the spars of vessels are subjected, must be a varnish of superior quality; and it was a mark of credit to call a varnish spar varnish, for, if it will last on spars, it will last anywhere in an exposed position.

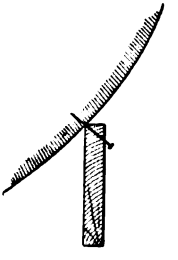

FIG. 31

A varnished deck is all very well for a boat that is going to have some care spent on its upkeep, such as wiping it off after a rainstorm so that it will not show mottled, or for a boat that is to be kept in a boathouse. But in the case of a craft that is to be left at a mooring buoy for days at a time without attention, varnish is a poor finish to have on a deck. A plain painted deck is far more substantial, while a painted canvased deck is best of all for a small boat. A yacht with a crew living aboard can keep varnished decks swabbed off or can holystone and wash down the bright decks, or decks where the wood is left bare and laid, generally, from clear, selected, narrow planks of white pine. In the southern waters, where the sun's heat is intense, canvas covers are made to fit the deck and these protect the wood, somewhat, from the sun.

EXPOSED METAL WORK

40. All the exposed and underwater metal work should be carefully inspected before the boat is launched. Very often it will be found that the fastenings holding the lower end of the stem band are eaten away by rust, or the fastenings that hold the skeg or shoe on aft may need replacing. A good illustration

of how the galvanic action of salt water affects exposed iron is shown in Fig. 32, where the propeller was made of bronze while the rudder was of iron. It is poor economy not to take every precaution to look after and repair such things before the boat is placed in the water. Most men display considerable impatience to get the boat afloat and get some use of it before it is properly overhauled, but should one of the parts referred to get out of order they will most likely pay dearly for their experience.

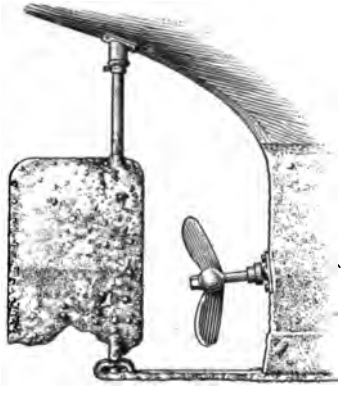

FIG. 32

In boats where the pintle fits into a hole in the skeg, there is usually a small hole drilled through it for the insertion of a cotter pin, as in Fig. 33, which prevents the rudder from being pulled out. It is very important that this pin be put in place, for many men have lost their boats' rudders by neglecting to do this. When the rudder strikes something it is apt to be lifted up out of the skeg and when it drops down again the pintle may not go back in the hole. Some rudders are so flimsily hung that it requires very little for them to get out of order; and if caught when sliding over a rope or it touches the bottom the rudder is liable to be torn off.

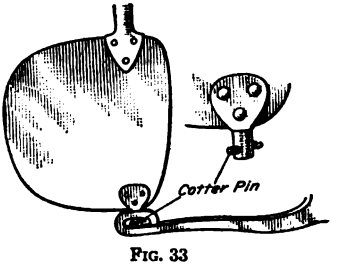

FIG. 33

CARE OF STUFFINGBOXES

41. Advantages of Inside Stuffingbox.—It is highly desirable that the boat's propeller shaft should be equipped with an inside stuffingbox, so that in case the box becomes leaky it can be easily tightened and the leak stopped. Many of the small launches have only an outside stuffingbox; as a result,

should the propeller strike a log and slightly bend its shaft, the wabbling revolutions will wear the stuffingbox so as to develop a bad leak. There are plenty of cases, too, where a rope has wound up in the propeller and loosened the cap on the stuffing-box so as to make it leak.

The only remedy for a leaky outside stuffingbox is either to send a man overboard and, working under water, try to tighten the box, or else to beach the boat in order to get at the stuffing-box, as shown in Fig. 34. The job, in either case, is not a very pleasant one. Every precaution should therefore be taken with an outside stuffingbox, to see that it is properly packed before

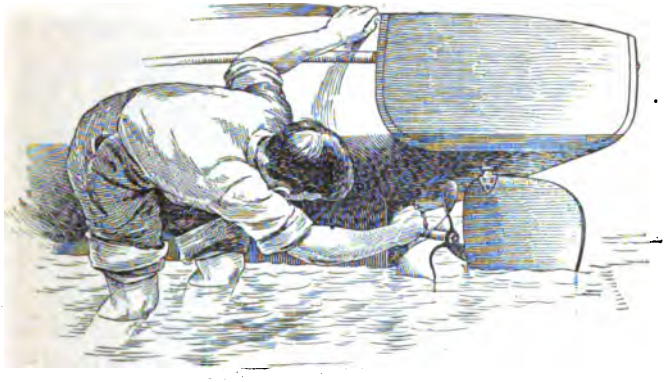

FIG. 34

the boat is launched. To do this, unscrew the cap on the stuffing-box, slide it along the shaft up against the propeller and, with the end of a file, pick out the hemp rings with which the box has been packed. Some men, in an emergency, use cotton wicking dipped in oil and flake graphite wrapped around the shaft, until they get a wad big enough to fill the recess in the stuffingbox. But cotton packs down solid and is soon useless, whereas, hemp retains its elasticity much longer and does not rot so quickly. One can buy hemp packing in a square woven cord by the yard, in boxes; it comes in various sizes from $\frac{1}{4}$ inch square up.

42. Packing a Stuffingbox.—To pack a stuffingbox properly, cut this square cord in pieces just long enough to go

once around the shaft. Put them in one at a time, smeared with oil and graphite, and tuck them into the recess in the stuffingbox, shift the joints so that no two come in the same line. When the cap is screwed back on again, these rings will be com-

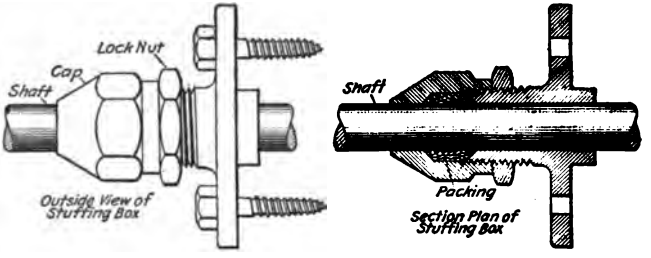

FIG. 35

pressed and squeezed against the shaft so that no water can leak in, and yet the graphite will allow the shaft to revolve freely. Another nut, a narrow one called *locknut*, shown in Fig. 35, should be screwed back against the cap to prevent the cap from unscrewing.

The best way is to have an outboard stern bearing and an inboard stuffingbox, as shown in Fig. 36. There is nothing about a plain stern bearing to get out of order and the stuffing-box can then, at any time, be tightened from the inside of the boat, in case it leaks.

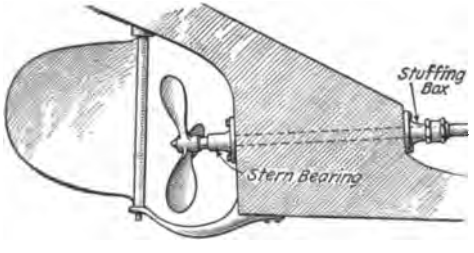

FIG. 36

Another important point is to see that the water intake pipe is secure and that it has a grating or sieve strainer over it, to prevent sticks or other matter being sucked up in the pipe to jam and clog the pump; also, when painting the bottom, a person must be sure not to clog the holes of the sieve with paint.

DECK FITTINGS

43. On deck, all the cleats and rail stanchions should be tried, to see that none are loose. Sometimes the head of a screw holding the flange of a rail stanchion on the deck breaks off, when it is a difficult matter to get out the broken screw. The best way to remove it is to score the screw with a cold chisel so that a screwdriver bit will take hold and then turn out the screw and put a new one in its place. If the screw has pulled loose, the hole may be plugged with wood and then the screw put back in again. A drop of glue put in the hole helps some. If there is room, by reaming out the hole in the stanchion just a little, to get in a screw a size larger and a trifle longer, say, a $1\frac{3}{4}$ number 14, where a $1\frac{1}{2}$ number 12 came out, it is better to do so. Ever so little play or looseness soon grows worse, so that everything should be kept solid.

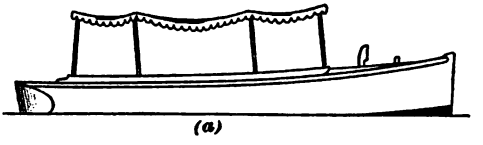

FIG. 37

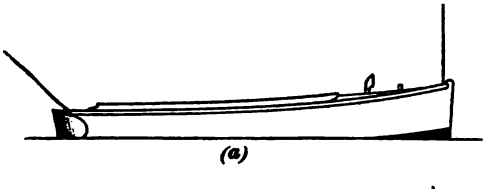

FIG. 38

44. Awnings and Flagstaff.—An awning on a small launch that hangs loose with its stanchions at different angles, as in Fig. 37 (*a*), is a distressed looking object compared to one where everything is stretched tight and straight. If it is necessary to use guyropes to stretch the awning tight, they should be

put on and drawn until all sagging is taken out of the awnings and the stanchions are parallel, as shown in (*b*).

The flagstaff is another object to which attention should be paid. If the bow staff stands perfectly plumb and the after one rakes or slants aft, as in Fig. 38 (*a*), the appearance is much

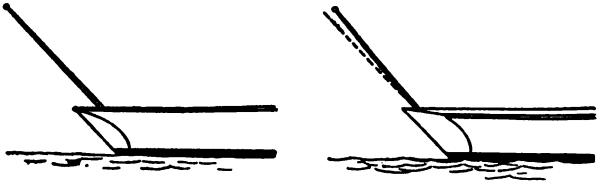

FIG. 39

neater than when the two staffs are set, as shown in (*b*), with the bow staff out of plumb and the stern staff raised too high. If the boat's transom has a slant or rake of any extent, the stern staff should have exactly the same slant as the transom, as illustrated in Fig. 39. Many boat owners never give these

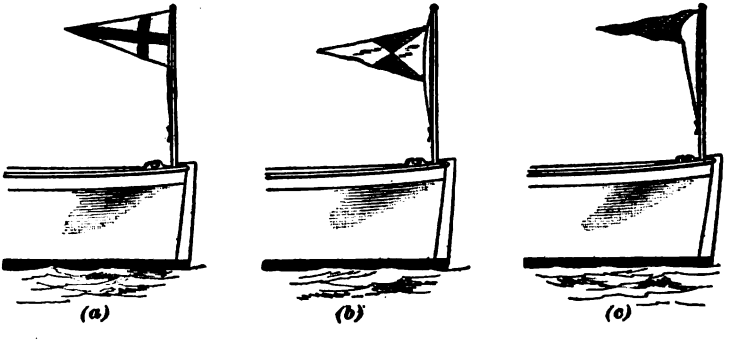

FIG. 40

points the slightest consideration, yet they wonder why it is that another man's boat, where these points have been looked after, appears so much neater than theirs.

45. The proper hoisting of the flags helps the appearance of a boat. Some men hoist them up very carelessly. They do not pay attention to whether the flag is clear up to the top of the staff or not, as in Fig. 40 (*b*), or whether the flag halliards are

tight so the flag will fly out flat and true, as in (*a*), or whether it trails aft, all rolled up, as in (*c*).

If the yacht is big enough to carry a rowboat or tender on her davits, care must be taken that the boat is not hoisted too high at the bow, as shown in Fig. 41, with the stern hanging down or

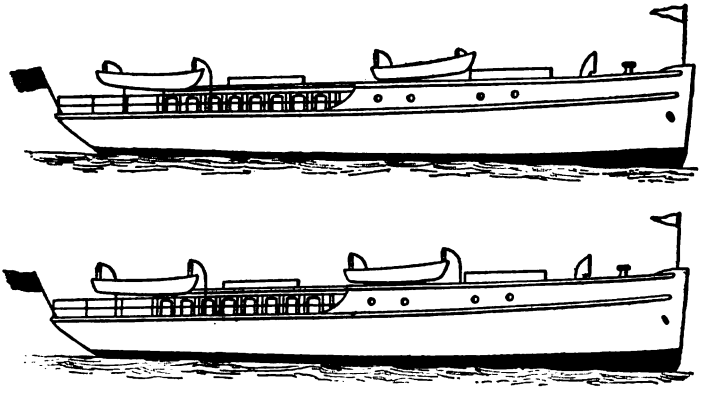

FIG. 41

otherwise out of line with the sheer line of the yacht. Also, after the boat is properly hanging in the davits, care must be taken to pull out the plug in the bottom, so that in case it rains hard during the night, the boat will not get so full of water as to break the falls or the davits.

UPKEEP AND ORDER

46. When the boat is placed in commission the entire outfit of cushions, lights, flags, anchors, etc., should be assigned to its proper place and everything should be kept in such order that in an emergency any tool, piece, or apparatus that may be wanted can be found instantly. The engine tools should always be kept in a locker near the motor. The *running lights*, that is, the side lanterns and the bow and stern lanterns, should be kept in a separate locker, together with the can of oil, the spare wicks and the funnel for refilling the lamps. It will be found that this systematic arrangement of things and keeping them in order will add considerably to the pleasure of boating,

and will soon become a habit. To know where to find anything wanted may mean a great deal in an emergency. It is one of the first rules of boating to have a place for everything and keep everything in its place.

The same is true with the upkeep of the boat. A careful boat owner takes pleasure in seeing that everything is kept shipshape. He gets into his tender and rows off to survey his yacht at a distance and see that everything is as it should be; that there are no loose rope ends hanging over the side, that the awnings are all stretched straight and true, and that the yacht, in all respects, looks neat and orderly.

TRIM AND SEAWORTHINESS

47. The way a boat sets on the water is called her **trim.** Many boats trim nicely to their painted water-line as they lay still at their moorings; but when the motor is started and the boat is pushed through the water by the propeller, her stern settles down quite low and her bow crowds up high out of water. Such a boat is said to be trimmed too deep by the stern. If it is a small boat, the passengers should sit far enough forwards to help hold down the bow when under way; if it is a large yacht, a suitable amount of ballast should be stowed in her bottom, well forwards. She might better be slightly trimmed down by the head, so that when starting to gain speed she will trim more on a level line. A boat that is cut up too quickly, so that her after lines are too abrupt and steep generally *squats*, which means being trimmed too low by the stern, as shown in Fig. 42 (*a*).

The opposite to being trimmed too low by the stern, is a boat trimmed too low at the bow or head, as in (*b*), which is a far worse condition. The weights in such a boat are too far forwards and she is not only in danger of being run head under when the bow dives under a wave, but she does not respond readily to the wheel and is inclined to take a sheer off to one side or the other, in spite of the efforts of the helmsman to make her run a straight course. Trimmed down by the stern is much to be preferred to trimming down by the bow.

48. **Ballasting a Boat.**—Inexperienced persons often consider a boat just acquired to be perfect in all respects. But motor boats to be comfortable, seaworthy, and easy to handle need considerable attention in regard to their trim. It is surprising how the intelligent use of a little ballast will increase the comfort on a boat. Assume, for instance, that a party starts a trip on a dead calm sea and that the boat runs along as smoothly as possible, but that after a while a breeze springs up and small waves begin to form. When the waves grow larger, the boat starts to pitch a little, fore and aft, the bow bobbing up quickly, followed by an equally sudden drop. If, under these conditions, one-half of the party on board was instructed to sit in the after end of the cockpit and the other

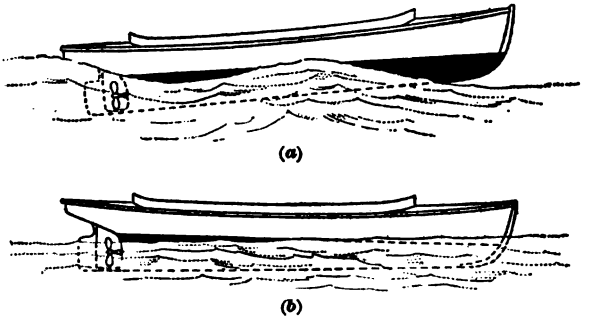

FIG. 42

half takes places well up forwards, this distribution of weights will act in the same manner as when a long pendulum is added to a clock. It will make the boat pitch less, the bow will rise and settle more slowly, and the whole movement of the boat will become more easy and uniform. The same result can be obtained by shifting a little iron ballast forward and aft, under different conditions, until the boat is trimmed just right. Designers try to distribute the weights on large yachts so as to give the boat a correct trim and stability, but it is often necessary to add some *trimming ballast* as it is called, to get good results. The difference in the behavior and pitching motions between a boat properly trimmed and ballasted and one that is not is very pronounced.

49. The same is true with the sidewise, or rolling, motion. Most persons imagine that all the weight should be in the middle of the boat, which is not the case. Distributing the weights along the keel may do on very narrow, deep boats that have but little natural stability. But a wide, flat boat with all the ballast in the middle, will right herself so suddenly when rolled over by a wave as to be very uncomfortable, almost throwing those on board off their feet. By spreading the ballast across, or stowing part of it on one side and part on the other, as in Fig. 43, a flat-bottomed boat can be made to roll as slowly and as easily as can be expected. It is for this reason that steamships stow the coal in bunkers placed against the sides of the ship, as shown in Fig. 44 (*a*), and that stevedores, when loading a big sailing ship, put such heavy stuff as railroad iron, not in the bottom where one would suppose it would go to make the

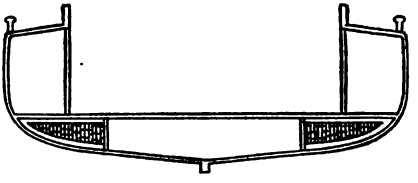

FIG. 43

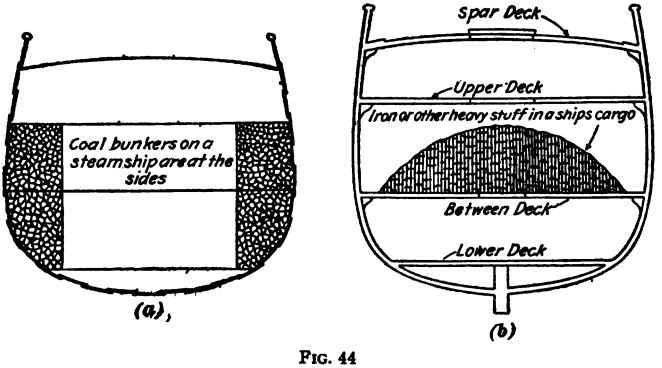

FIG. 44

ship steady, but at some distance above the keel on what is called the between decks, as is shown in (*b*). This makes the ship roll much more slowly and more easily and the strain on her masts and shrouds is much less than would be the case if all the heavy cargo were in the bottom. Many a hard-rolling motor yacht has been transformed into an easy-swinging craft by having her

rowboats swung and securely lashed to davits on each side of the yacht. She still rolls, but the period of roll from side to side is very much lengthened, and she does not come back so quickly as to cause a man to be thrown off his feet.

CARE OF BOAT IN WINTER

HAULING BOAT OUT OF WATER

50. Use of Plank and Rollers.—Many men who can operate their boats when afloat are at a loss how to handle them on the approach of winter, when snow and ice necessitates the hauling out of the boat. A great deal naturally depends on the size of the boat and the slope of the beach where she is to be hauled out.

An open boat up to about 20 feet, if of the old-style straight-keel type, can be hauled out by three or four men by merely laying two boards, one along each side of the keel, then prying the boat up high enough to slip a couple of wooden rollers, pieces of an old spar about 4 inches in diameter, under the keel on top of these boards, and pushing her up by hand. If wooden rollers cannot be obtained, pieces of 3-inch pipe will serve equally well.

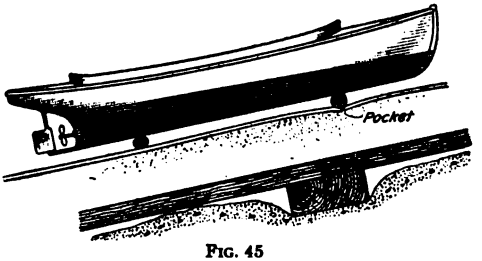

FIG. 45

In localities where tides prevail, advantage should be taken of a high tide to float the boat as high up on the beach as possible. If the grade is steep, and the boat heavy, tackle should be used to haul it up, a man or two being placed on each side to steady and keep the boat on an even keel. Where there is no tide, the planks and rollers must be pushed under the boat until her weight is brought to bear on them. Plank should always be laid ahead of the boat as she goes up the beach, taking

the planks and rollers out from under aft and shifting them ahead as the boat rolls off.

51. Care must be taken not to use planks that are too thin, good stout ones from 2 to 4 or even 6 inches thick will work

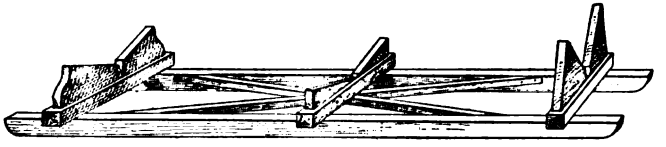

FIG. 46

better than thinner ones; and where new lengths of plank are placed ahead of the boat the sand or dirt should be scraped

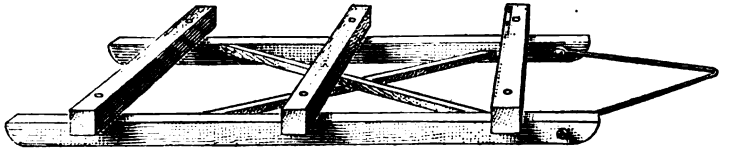

FIG. 47

away and a stout block or timber laid under the joint, as shown in the lower part of Fig. 45, so that as the rollers bear on the end of a plank they will not bury this end. If this happens, the rollers are in a pocket, as shown in the upper part of Fig. 45, and it is impossible to push or pull the boat until these ends have been relieved of the weight by prying up on the boat and the planks padded under their ends to make them level.

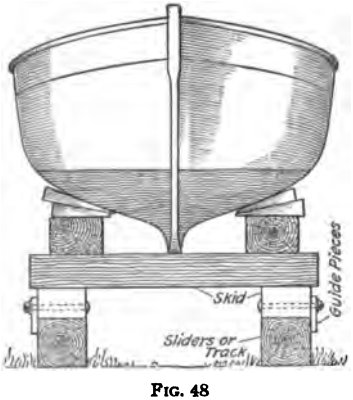

FIG. 48

52. Skids and Cradles. If the propeller shaft of a boat projects below the boat so that the rudder and the propeller make it impractical to roll the boat along on her keel, or if the boat is too heavy for men to hold her upright, she must be landed on a framework of wood

called a cradle or skid. Properly speaking, a **cradle**, Fig. 46, is a stout, well-built framework specially made to fit the under body of the boat, but a **skid**, Fig. 47, is constructed simply of two fore-and-aft pieces with several crosspieces bolted to them and the whole braced by diagonals, so that the skid will not close up like a parallel ruler.

A boat landed in its cradle is held upright and secure from heeling, but on a skid the boat has to be blocked up and braced

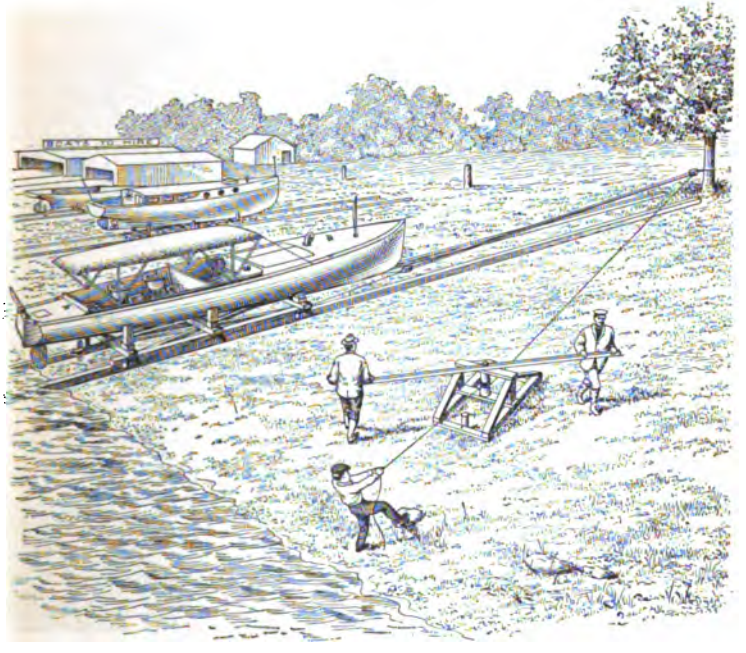

FIG. 49

by temporary blocks of wood. If it is known how far the shaft projects below the bottom, blocks of wood can be cleated fast to the skid's crosspieces and so the weight of the boat can be borne by these blocks, the shaft going between them. Some judgment must be used, however, to see that the supporting blocks will come under the motor, if it is a light racing hull with a big heavy motor, or the boat is likely to be strained.

53. Tracks for Skids.—On the two outer edges of the fore-and-aft pieces of the skid there should be bolted a guide piece of plank to prevent the skid from sliding sidewise off of the greased timbers upon which the boat is to be pulled up the beach. These guide pieces are shown in Fig. 48. The timbers forming the track should be stout enough not to bend, at least 4 inches by 6 inches or 6 inches square, and in fairly long lengths. They should be placed with the smoothed edge up. Where the planks extend under water they can be held in place by stakes driven into the beach and nailed to them.

By greasing the tops of the planks with tallow, or some heavy grease, the skid with the boat floated on to it can be landed on them and hauled up by means of a tackle. Almost any amount of power can be obtained by hooking one tackle on to the *fall*, as the hauling end of another tackle is called, or by using men, a horse, or some sort of capstan, as shown in Fig. 49. Before commencing to pull up the boat, all sand and grit must be removed from the sliders or tracks. If the skid does not start when there is a good strain on the tackle, hitting the back end of the skid with a sledge will often give it a start, after which it is easy to keep the boat going by keeping a uniform strain on the tackle.

BLOCKING A BOAT

54. When the boat is hauled up as far as is necessary to escape damage by water or ice, bearing in mind that spring tides are often a couple of feet higher than ordinary tides and that ice cakes are often jammed up beyond the high-water mark, it should be blocked up for the winter. In case the skid is to be used to haul out other boats, the boat should be slid off and placed on blocks. If the boat is a heavy one this can be accomplished as follows: Preparatory to sliding her off the skid, raise the boat high enough to block her up properly; the raising is done with a screw or hydraulic jack, or the boat may be pried up with a beam as a lever. Then, after she is blocked up, lift the boat a few inches more, to get the greased sliders under her keel, and then draw her sidewise off the skid and block her up for the winter. This operation is illustrated

in Figs. 50 and 51. If known beforehand that the boat must be taken off the skid, it is far better at the outset to put on the skid blocks high enough to hold the boat up, so that sliders can be put under her without having to do any jacking or prying.

55. Cribwork for Support of Boat.—When building up a pile of blocking to support a boat, it is not enough simply to pile one block of wood on top of another, as in Fig. 52; such a pile will tip over too easily. Blocks should always be *cribbed*, as it is called, by placing them alternately across one another in pairs, as shown in Fig. 53, with a single block on top for the keel to rest on; such a pile is steady and is not easily disturbed. When building a cribwork the upper blocks should always be put a little closer together than those under them, so that the pile will gradually grow narrower at the top.

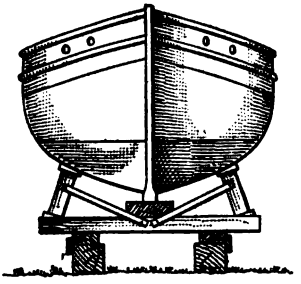

FIG. 50

When the boat is placed where it is to be left for the winter, a cribbing should be built under her keel, about one quarter her length from the bow, the loose top soil being scraped away so that the two lower timbers are on hard ground. Then, a quarter of her length from the stern another cribbing should be built, but the boat's stern should be raised until she is level, just as she sets on the water. If not properly leveled, any water in her bilge

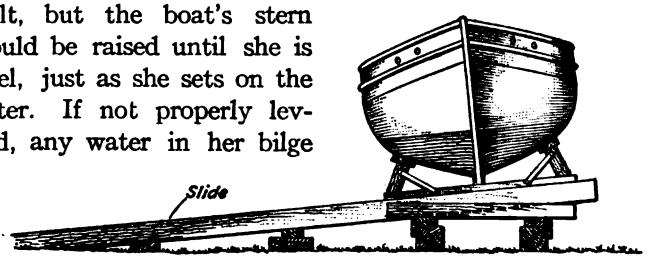

FIG. 51

will not run out and unless holes are bored on each side to drain it, the garboards may be damaged by the water freezing and forcing the planks loose along the keel during winter or rot them during the warm weather in the spring. Also, any water

that may remain on deck or in the cockpit, will form puddles to discolor and rot the wood. But if the boat is properly leveled, such water will drain off through the scuppers. No

FIG. 52

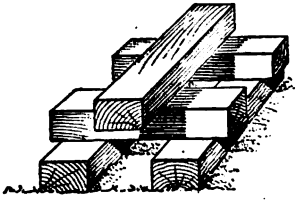

FIG. 53

nails or tools should be left on deck or cabin tops during winter, as they will rust and stain the wood on which they lie.

56. Shoring the Boat.—Next in importance to the keel blocks are the **shores,** or the braces, put up on each side to keep the boat in an upright position. The proper place for the shores is directly opposite the cribbing under the keel. In this position, if the boat settles at one end, the shores will do less damage than if placed at any other part of the hull. If forward of the cribbing and the forward end of the boat should settle, the bilge shores will push very hard against the hull, as all the weight of the boat will be placed upon them; if aft of the cribbing, as the boat settles down forward, it is raised off the bilge shores. When placed in line with, or opposite the cribbing, the shores act in conjunction with the former and make a staunch support for the boat.

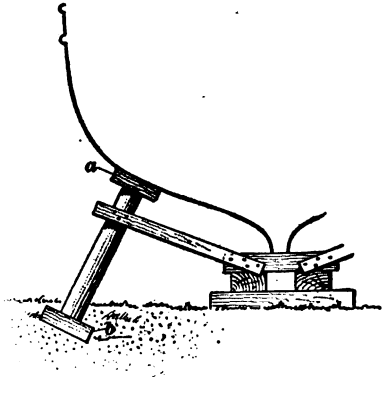

FIG. 54

To prevent the shores from straining, and perhaps breaking a plank, the shores should never rest directly against the boat. A short, thick plank *a*, Fig. 54, should be placed between the shore and the boat, in order to distribute the strain exerted

by the shore over two or more frames of the boat. Also, to prevent the lower end of the shore timber from sinking down into the ground and thus reducing the support to the hull, a thick plank, *b*, should be laid on the ground and the end of the shore set on it, as shown. To make it doubly secure, the shore may be nailed to both planks when in place.

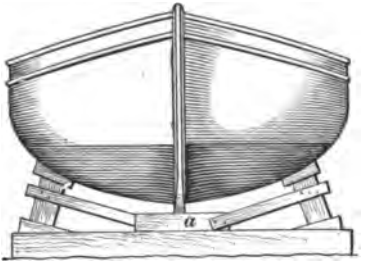

FIG. 55

If the boat is a small one, several old railroad ties, or pieces of timber about as long and as heavy, may be used as a foundation for the cribwork and the plank supporting the keel allowed to rest on them, as shown at *a*, Fig. 55. Then, from both ends of these timbers, the bilge shores may be put up on each side of the hull. To prevent their falling down, the shores should be steadied by nailing a light piece of plank to both shores and keel block. It is a good plan to brace, in this way, all bilge shores, no matter what the size of the boat may be.

COVERING BOAT DURING WINTER

57. A boat should always be protected from the ice and snow of winter. This may easily be done by erecting on the boat a framework, like that shown in Fig. 56, and covering it

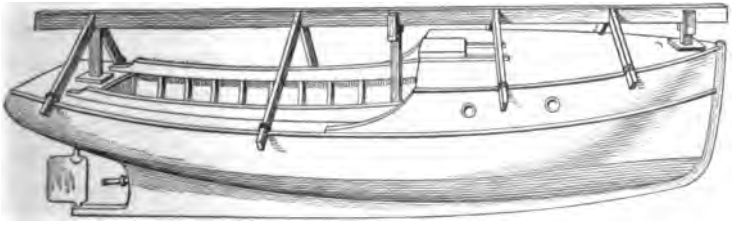

FIG. 56

with canvas or tar paper. This framework consists of a ridge pole and its supports. The uprights supporting this pole should be placed upon short planks, so as to distribute the weight of the

frame and covering and not dent the deck. The braces should extend beyond the sides of the boat and should be lashed to the sides with cord or rope, rather than fastened with nails, which will mar the paint or varnish. Merely wrapping a boat in canvas, letting the canvas lie flat on the deck, as it would on a raised-deck cruiser, will not afford much protection, for the canvas is likely to get wet and freeze to the deck, and for this reason they should be kept apart so there is an air space between.

58. The pitch of the cover should be sufficiently steep to prevent any puddles of water forming in the sag of the canvas cover. If the canvas is allowed to hang down so as to shelter the upper part of the boat's side, the top sides will be in a far better condition and require less effort to paint and fix them up in the spring, as the sun will not get a chance to shrink the wood so much as when it shines right on the boat.

During the warm spring days, when the worst of winter has passed, the cover should be opened a little near the top, at both ends, to permit the warm air to escape. If this precaution is not taken, the foul warm air of the interior will promote decay and otherwise injure the woodwork.

All the brass work and deck hardware should be coated with vaseline or Albany grease, to prevent their tarnishing during winter. This covering can be removed in the spring and the brass work easily polished again.

CLEANING OF BOAT

59. When hauling a boat out of water, if there is a scum of dirt on the bottom, a person standing in the shallow water should scrub off all this scum, with a broom, as the boat comes out of water. Dirt accumulated on the bottom is easily removed while wet, but if allowed to remain and dry on the paint it will be difficult to get it off, even with a scraper and sandpaper. A steel wire bristled scrub brush is very effective to use on a boat in this condition. In Fig. 57 is shown a typical case of neglected cleaning when the boat was hauled out. The labor of scraping and brushing the underbody of a yacht covered with dried-up barnacles and slime is not an easy one.

Everything should be taken out of the boat and the interior thoroughly aired, swept, and scrubbed clean, even under the floor boards where, on so many boats, dirt is permitted to collect. This dirt, if allowed to lie in the boat, promotes decay in the wood and produces that close musty smell so objectionable in some boats.

FIG. 57

A boat should not be let go through the winter with parts of her woodwork rubbed bare of all paint or varnish; all such parts should be given a coat of paint or varnish for protection.

BOAT HOUSE AS WINTER QUARTERS

60. Where such accommodations are available, it is the custom on most of the rivers and fresh-water lakes throughout the country to keep boats tied up in a slip under a boat house, and before winter sets in the boat is hoisted up and placed on timbers laid across the slipway under its keel. When housed in this way, the boat needs no other covering. All the fittings are generally removed and placed in lockers built in the boat house, to make the boat lighter to lift up.

Some of the larger and more elaborate boat houses have iron or wooden beams down under water that cross the slipway and over which the boat floats, as shown in Fig. 58. Whenever it is necessary to raise the boat to repair the rudder or propeller, or when the boat is to be raised completely out of water for the winter, she is lifted up by turning a wheel or lever handle, which is connected to a nut through which a long threaded iron rod extends, its lower end being fast to the cross-beam under water.

61. Where this expensive outfit cannot be afforded, the differential chain hoists, hooked into a beam overhead, or an ordinary rope tackle, is used to hoist the boat. If the boat is

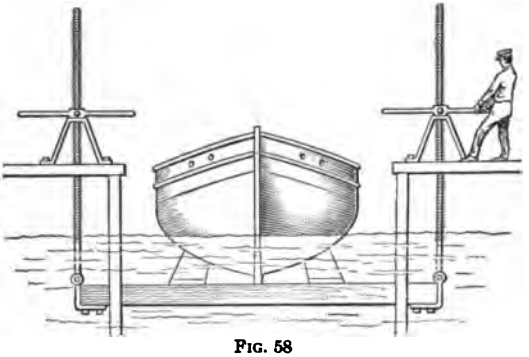

FIG. 58

a light one, such as an open runabout, beams are not needed under the boat's keel. A stout piece of rope cable may be passed under the boat, but if she has a shaft projecting below the bottom, this rope sling must be put between the shaft and the bottom, so as not to spring or strain the shaft. Both ends of this rope sling should be brought up over the middle of the boat and hooked to the hoisting tackle. Before strain is applied to the sling, the boat's planking should be protected by old soft pieces of canvas, or fenders, placed so that the hard rope will not cut the paint when the boat is lifted, as shown in Fig. 59. As the pinch upon the deck edge is often so severe and liable to damage the boat, a piece of a joist, or an oak spreader, with notches cut in the ends to steady the rope, is generally laid across the coaming, as shown in the figure. This will prevent the rope squeezing the boat so as to cause damage. By using two of these slings, one near each end, the boat can be hoisted out safely.

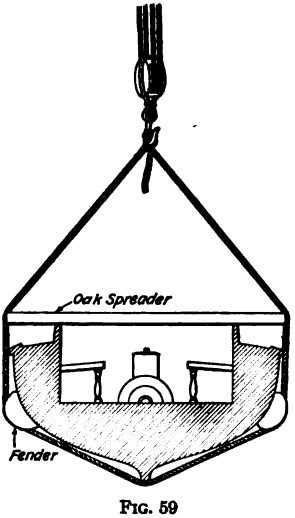

FIG. 59

PLANS AND DRAWINGS

62. To persons not familiar with the readings of plans and drawings representing the worked-out design of motor boats and other craft, the following brief explanations will prove useful, especially in cases where a prospective yacht owner must judge the qualities of his boat from drawings submitted by the designer.

63. Plans.—In general, three views are necessary to project the shape of a boat. These views, with the necessary lines and curves, are shown in Fig. 60. The **sheer plan** is a side view of the proposed boat. The **half-breadth plan** is a view looking from above the boat; one side only, being drawn, because the two sides are alike. The third view is known as the **body, or section, plan,** because it represents the form of the body of the boat in sections.

64. In the sheer plan is shown the load water-line, L. W. L., which is extended across the body plan. It will be noticed that this water-line is divided by vertical lines at equal distances apart, and that these lines are numbered consecutively from bow to stern. These lines are projected to the half-breadth plan below, dividing it into an equal number of parts. To find the shape of the body of the boat at any one of these lines, the different intersections of the line in the half-breadth plan are plotted and projected in the body plan. Usually, in the plotting of sections, all forward of midship line, in this case 7, are drawn on one side of the center line, while sections aft of the midship line are plotted on the other side. Thus, in the body plan of Fig. 60, the forward sections are to the left and the aft sections to the right of the center line.

The sheer plan is further divided by horizontal lines running parallel with the load water-line, and which, like the latter, are extended across the body plan. Any number of such *water-lines*, as they are called, may be used, but for the sake of

clearness, only two are here shown. By measuring the distance of the water-line from the center to each section in the body plan and then plotting them in the half-breadth plan, the area of the boat enclosed by each line is shown.

65. In the body plan are shown two dotted vertical lines; and, running from the center, intersecting the plan at different angles, full lines. The former are known as **buttocks** and the latter as **diagonals**. The buttocks are drawn at a fixed distance from the center of the boat in both the body plan and the half-breadth plan. From the latter plan, they are projected to the sheer plan, as shown in Fig. 60, corresponding letters x, x_1, x_2, and y, y^1, y^2 indicating the same points of intersection in both plans.

The diagonals are very useful for the purpose of fairing up and adjusting the lines of the boat so that frames and planking of body will fit together smoothly. In Fig. 60, diagonals *1* and *2* are plotted on the opposite side of the half-breadth plan by measuring and transferring the distances of each point of intersection in the body plan. Thus, the distance of *n* on diagonal *1* from the center line in the body plan, is equal to *n 2* in the half-breadth plan. Likewise, the distance of the points *z*, *u*, and *e* of diagonal *2* are equal to the distance from the center line to the corresponding letters along diagonal *2* in the half-breadth plan. The same applies to corresponding letters *b*, *c*, and *d* and *p* and *q* of diagonals intersecting the aft sections of the body plan.

66. It is evident that before the plans of a vessel are drawn, the general characteristics of the boat must be decided upon. This may be done either by a preliminary set of drawings in which the general arrangement and principal features are embodied, or plans may be drawn from a worked-out wooden model of the proposed boat. In the first method, the actual plans and lines are prepared from the preliminary set of sketches, and, based on them, calculations are made of the weights, stability, trim, strength, speed, etc. If the shape of the hull has been determined by model, the plans are drawn according to results ascertained by the experiments of the model.

When working out his design, the naval architect uses special tools and instruments. Among them are the splines and weights for drawing the various curves, such as buttocks, water-lines and diagonals. The spline *a f*, Fig. 60, is a flexible batten, generally made of celluloid, or hard rubber, though the best designers use lancewood battens altogether, as rubber or celluloid battens are liable to kink out of shape. When properly adjusted, these splines produce a fair curve passing through the desired points of intersection. To hold the spline in place, weights of the shapes shown in the figures are ranged along it at suitable intervals. The spline shown is adjusted to draw the aft portion of the diagonal *1* after the intersections taken from body plan are plotted.

67. Curve of Areas. A curve sometimes shown on the plan of a boat is the so-called **curve of areas,** which is obtained as follows: After the area of each section below the load water-line, in square feet, has been calculated, these areas are laid out in some linear scale. Thus, if the midship section contains 20 square feet, a distance of 2 feet is laid off vertically from the center line on the half-breadth plan on, say, an inch scale, assuming each foot on that scale to represent 10 square feet; the areas of all the other sections are projected in the same way on their respective lines. If no error has been made in calculating the areas, a batten or spline, bent through the extremity of each line, should make a fair curve, as shown in Fig. 61. By means of this curve the area of the midship section up to any mean draft may be determined.

68. Center of Buoyancy.—Designers using the symbol of *dead flat*, 𝔐, to indicate the midship section of the boat, sometimes employ the same symbol to indicate the *center of buoyancy*, which in most motor boats is very close to the middle of the water-line; if anything, it is a trifle aft of it, as in Fig. 61. This center of buoyancy is identical to the center of gravity of the area enclosed by the curve of areas just referred to. It is the point at which the boat is supposed to pivot or balance, theoretically, if made to float exactly even with the load water-line as drawn. In case a great deal more weight of wood enters

into her construction aft than forwards, the boat may float with her stern up, or vice versa, according to distribution of weights. Designers have to calculate these weights and so distribute the weight of the motors, gasoline tanks, water tanks and everything else to be carried, as to bring the boat down just level with her L. W. L. When floating at that line the center of buoyancy will be where the calculations showed it came.

69. Construction and Accommodation Plans.—Besides the lines shown in Fig. 60, a set of plans of a boat includes the construction plans and the interior layout, or accommodation

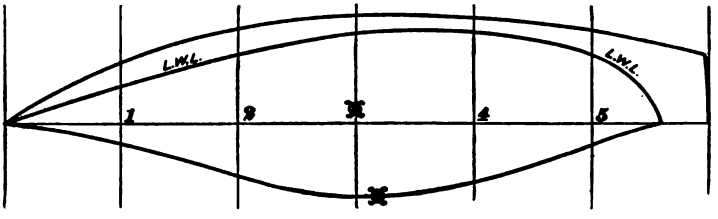

FIG. 61

plan, also a tabulated list of all measurements necessary for reproducing the lines known as a *Table of Offsets*, and a complete list of specifications.

70. Laying Down a Boat.—After the drawings and plans are completed, the boat is laid down on the mold-loft floor in full size as a whole or in parts. The *laying down* consists in cutting lines representing those that appear on the plans. From the mold-loft plans, or directly by measurements from the drawings, the scrive board, molds, and templets are prepared. The *scrive board* is, in effect, a full-sized drawing, showing the shape of every frame of the boat; but it is not always used, templets being sometimes built up from the smaller drawings and carried directly to the bending slab where the frames are shaped. Detail drawings are made of all parts of the boat, showing, on a convenient scale, their exact shape and size.

MARINE GASOLINE ENGINES
(PART 1)

PRINCIPLES OF OPERATION

TWO-CYCLE PRINCIPLE

DEFINITIONS AND NAMES OF PARTS

1. Marine gasoline engines belong to the class of engines, or motors, known as *internal-combustion engines*, so called because power is obtained by burning the fuel within the engine cylinder. This fuel consists of a mixture of air and vaporized gasoline, kerosene, or some other liquid. The burning of the fuel, which is so rapid as to be practically instantaneous and is called the *explosion*, produces gases of high pressure that act against a movable piston, driving it outwards and doing the required work through the proper mechanism. Provision is made by means of *ports* and *valves* in the cylinder walls for admitting the fuel and for allowing the burned gases to escape.

2. Some of the essential parts of one of the simplest forms of marine gasoline engines are shown in Fig. 1, which is a cross-sectional view of a vertical, single-cylinder, two-port, two-cycle engine. In this illustration the cylinder is considered as being cut in half crosswise, and the front half removed, exposing to view the various parts. The *cylinder* proper *a* is surrounded by the *jacket space b*, through which water is passed for the

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purpose of cooling the cylinder walls, which become hot from the repeated explosions; the cylinder is supported by the air-tight crank-case *c*. The movable *piston d* is connected to the *crank e* by the *connecting-rod f*, which is attached at the top by the *piston pin g* and at the bottom by the *crankpin h*; as the piston moves up and down it causes the crank to rotate, thereby turning the *crank-shaft*, which is rigidly attached to the crank. The crank-shaft cannot be shown, as it is concealed by the crank *e*. The piston is provided with *piston rings i*, which form an air-tight joint between the piston and cylinder walls. It is made hollow, so as to receive one end of the connecting-rod *f*, being of the so-called *trunk type*.

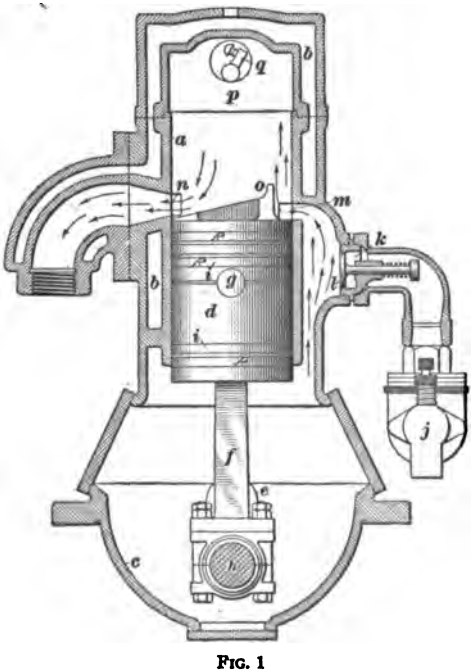


FIG. 1

3. At *j*, Fig. 1, is shown a device, called a *carbureter*, into which the gasoline, or other liquid fuel, is led, vaporized, and mixed with air. This mixture, known as the *combustible mixture*, or *charge*, is taken into the crank-case through the *inlet port k*. It is prevented from flowing back into the carbureter by the *valve l*, which is held to its seat by a spring and will only open inwards. The charge is admitted to the cylinder through the *transfer port m* and the burned gases are allowed to escape through the *exhaust port n*. Both of these ports are opened and closed by the piston on its up-and-down movement. The projection *o* on the piston face is called the *baffle plate*, or *deflector*, and directs the charge into the upper

part *p* of the cylinder, known as the *compression space*, or *combustion chamber*. At *q* is a device, called the *igniter*, by means of which an electric spark is produced in the cylinder to fire, or ignite, the charge.

The burned gases resulting from the explosion in the cylinder of an engine are known as the *exhaust gases* or simply the *exhaust*. These gases are waste, and are allowed to pass out into the atmosphere.

4. Gasoline engines may be either *vertical* or *horizontal*, depending on the arrangement of their cylinders. Engines having cylinders placed vertically like that shown in Fig. 1, are classified as vertical engines, while those with their cylinders placed horizontally, that is, supported on one side, are horizontal engines. Practically all gasoline engines used on motor boats are of the vertical type.

5. The end of the cylinder attached to the crank-case in any engine is called the *crank-end*, while the other end is called the *head end;* that part of the cylinder wall enclosing, or covering, the head end is known as the *cylinder head.* The movement of the piston from the head end to the crank-end is called the *forward*, or *outward, stroke* and the movement in the opposite direction is called the *return*, or *inward, stroke.*

The engine is said to be on *dead center* when the crank and connecting-rod form a straight line. Two dead-center positions are possible: When the piston is at the end of its inward stroke, the crank is on its *upper*, or *inner, dead center;* and when the piston is at the end of its outward stroke, the crank is on its *lower*, or *outer, dead center.*

GASOLINE-ENGINE CYCLE

6. **A cycle** is any chain, or series, of events, or happenings, occurring over and over again in the same order. As applied to a gasoline engine, the term cycle refers to the operations, or events, that take place within the cylinder from one explosion to the next, and by means of which the fresh charge is drawn into the combustion chamber and exploded and the exhaust

gases are expelled. These events always occur in the same order and are repeated after each explosion.

The cycle on which an internal-combustion engine operates is one of the distinguishing features of the different types. Gasoline engines are classed as *two-cycle engines* and *four-cycle engines*, depending on the method of expelling the burned gases from the cylinder after the explosion and of taking in a fresh charge of combustible mixture; or, in other words, on the number of strokes of the piston required to complete a cycle, or for each explosion.

7. A **two-cycle engine** is one in which only two strokes of the piston, an inward and an outward stroke, are required to complete the cycle. The combustible mixture is admitted to the cylinder and the exhaust gases are expelled at the end of the downward stroke. The fresh charge is then compressed in the compression space or combustion chamber on the upward movement and exploded and allowed to expand and do work during the next downward stroke. In this cycle, the fresh charge is drawn into the air-tight crank-case and slightly precompressed so that it will readily flow into the cylinder against any pressure existing therein.

8. A **four-cycle engine** is one in which four complete strokes of the piston are required to complete the cycle; or, in other words, an explosion occurs once for each four strokes of the piston or two revolutions of the crank-shaft. In this type of engine, the fresh charge is drawn into the cylinder through the inlet port by a separate outward, or downward, stroke, and the burned gases are expelled for the most part by a separate upward movement of the piston. Generally speaking, one event occurs during each of the four strokes of this cycle; that is, considering the stroke upon which the charge is drawn into the cylinder as the first stroke, the mixture is compressed during the second stroke, burned during the third stroke, and the exhaust gases are expelled during the fourth and last stroke, after which the conditions at the beginning of the first stroke again exist and the cycle is completed.

9. It has been found that by compressing a charge before igniting it, a greater amount of mechanical power can be obtained from a given quantity of fuel. In other words, the efficiency of the internal combustion engine is increased by compressing the charge before igniting it. For this reason all marine gasoline engines compress the charge, by an inward stroke of the piston, before igniting it.

OPERATION OF TWO-CYCLE ENGINE

10. Characteristic Features.—The characteristic feature of the two-cycle gasoline engine is that but two strokes of the piston, corresponding to one revolution of the crank-shaft, are required to complete a cycle; or, in other words, each downward stroke of the piston is a power stroke. As previously explained, this cycle of operations is made possible by slightly compressing the charge before admitting it to the cylinder so that a separate intake stroke is unnecessary. In addition to this the burned gases are expelled at the end of the working stroke, thus eliminating a separate exhaust stroke.

11. Two-Port, Two-Cycle Engine.—The principle of operation of the two-cycle engine is illustrated diagrammatically in Fig. 2, which shows three cross-sectional views of what is known as a **two-port, two-cycle engine.** This is so named because only two ports, or openings, *a* and *b*, enter the bore of the cylinder, and distinguished from the *three-port* type in that the latter has three ports opening directly into the cylinder. However, the principle on which the two types operate is exactly the same. Each view in the illustration shows the cylinder and crank-case cut in half, exposing to view the various parts of the engine and showing the different positions of the piston. Except for the location of the inlet valve *c*, this engine is practically the same as that shown in Fig. 1, so that it is not necessary to name the different parts. The operation of the engine is as follows:

12. In Fig. 2 (*a*), it may be assumed that the cylinder has been filled with a combustible mixture, and the piston is

compressing this charge during its inward stroke. At the same time, the partial vacuum that is created by the upward movement of the piston draws a fresh charge into the crank-case *d* through the inlet valve *c*. At about the end of this stroke the mixture of gasoline vapor and air, which has been compressed into the compression space at the top of the cylinder, is ignited by a spark formed at the spark plug *e*. This completes the first stroke of the cycle, which is sometimes called the *compression stroke.*

13. During the second stroke combustion takes place, that is, the charge in the cylinder is burned. The piston is forced downwards by the rapid expansion of the burned gases and a rotary motion is given to the crank-shaft by means of the connecting-rod and crank. The outward motion of the piston on this stroke slightly compresses the mixture in the crank-case *d*, the inlet valve *c* having been closed at about the end of the first, or inward, stroke. This downward movement of the piston, called the *impulse stroke*, is illustrated in view (*b*).

As the piston approaches the completion of the impulse stroke, it begins to uncover the exhaust port *a*. As soon as the edge of this port is uncovered, the burned gases in the cylinder escape into the atmosphere. This escape is, or should be, rapid enough to allow the pressure in the cylinder to fall below that of the precompressed combustible mixture in the crank-case by the time the piston has moved out far enough to begin to uncover the transfer port *b*, through which a fresh charge begins to enter the cylinder and to drive out the burned gases.

View (*c*) shows the burned gases escaping and a fresh charge being taken into the cylinder. The baffle plate *f* deflects the incoming charge, so as to prevent its flowing out with the burned gases. The more or less complete expulsion of the burned gases and the drawing of a fresh combustible charge into the cylinder are accomplished during the time the piston is moving through a small portion of the latter part of the outward stroke and early part of the inward stroke. The ports are then closed by the piston during the early part of the inward stroke, after which the fresh charge is compressed in the

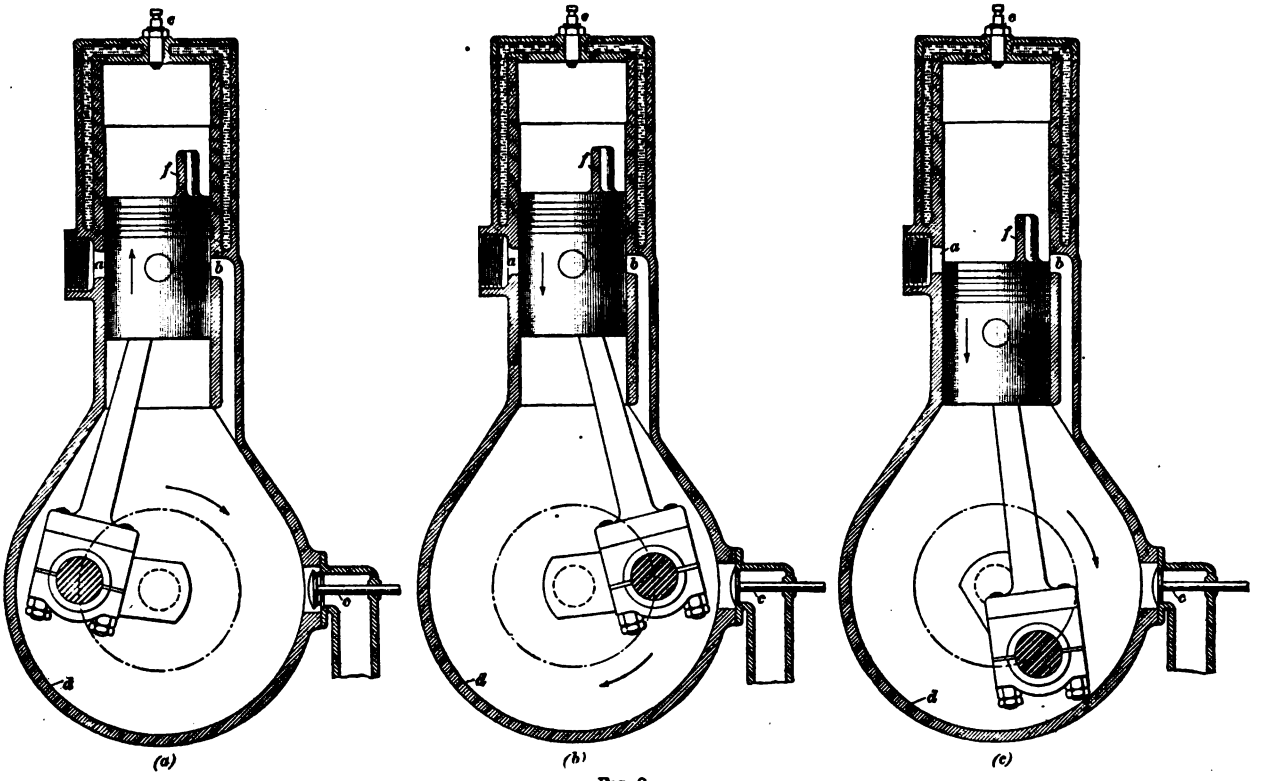


FIG. 2

combustion chamber, and more combustible mixture is drawn into the crank-case.

The inlet valve *c* opening into the crank-case may be operated either automatically by the suction of the piston or mechanically by means of a cam and push rod.

14. The series of operations taking place during the two-stroke cycle in the form of engine just described may be tabulated as follows:

TWO-STROKE CYCLE

CYLINDER	CRANK-CASE
FIRST STROKE, INWARD	
Compression; pressure rises; ignition near end of stroke, followed by explosion and rapid rise of pressure.	*Suction;* inlet valve open; pressure falls below atmosphere.
SECOND STROKE, OUTWARD	
Expansion; pressure falls; exhaust followed by entrance of fresh mixture from crank-case.	*Compression;* pressure rises to from 4 to 8 pounds; charging cylinder; pressure falls to atmospheric pressure.

15. Three-Port, Two-Cycle Engine.—The three-port, two-cycle type of marine engine differs from the two-port, two-cycle type in that the inlet port opens into the cylinder bore at a point near the crank-case and is opened and closed by the piston, instead of opening directly into the crank-case or into the transfer passage. This obviates the use of a valve of any kind, as the piston takes the place of valves, so that the engine is also known as a *valveless two-cycle engine.*

A three-port, two-cycle engine is illustrated diagrammatically in Fig. 3, which presents two cross-sectional views of an engine of this type, showing the piston in its bottom and top positions. The inlet port is shown at *a*, the transfer port at *b*, and the exhaust port at *c*. In the position shown in view (*a*), the piston *d* has just completed its downward, or power, stroke and a fresh charge is flowing from the crank-case *e* through the transfer passage *f* and transfer port *b* into the cylinder. The pressure

of this incoming fresh charge helps to drive the products of combustion, or exhaust gases, out through the exhaust port *c*, as indicated by the arrows.

In the position shown in view (*b*), the piston has just completed its upward, or compression stroke, and the combustible mixture from the carbureter is being drawn from the carbureter into the crank-case *e* through the inlet port *a*. The exhaust and transfer ports are both closed by the piston when it is in this position.

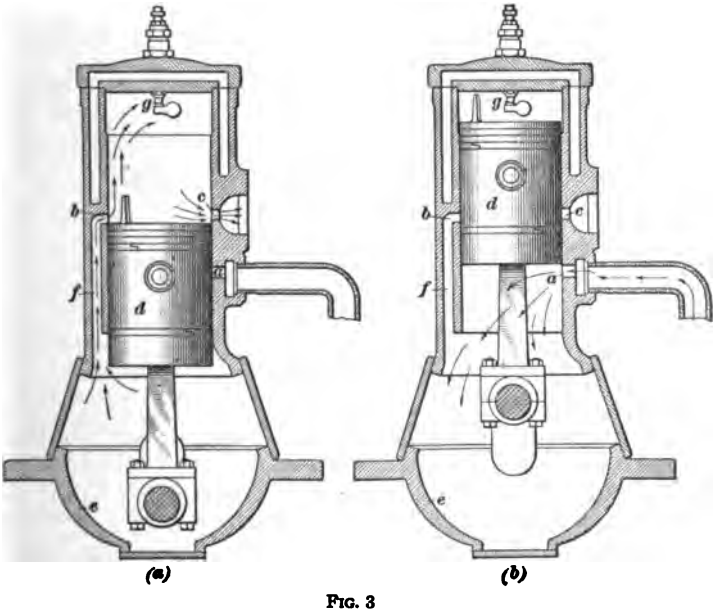


FIG. 3

16. The operation of the engine shown in Fig. 3 is as follows: Starting with the position shown in view (*a*), as the piston moves on its upward stroke the combustible mixture is compressed into the compression space in the upper part of the cylinder, and at the same time the inlet port *a* is uncovered by the piston so that a fresh charge is drawn into the crank-case by the suction of the piston. At about the end of this stroke, or in the position shown in view (*b*), the mixture in the upper part of the cylinder is fired by a spark produced at the igniter *g*

and the piston is driven downwards on its second, or impulse, stroke by the force of the resulting explosion. During this downward movement of the piston, the fresh charge that had been drawn into the crank-case is slightly precompressed so that it will flow into the cylinder through the transfer passage *f* when the transfer port *b* is uncovered. As the piston nears the end of its impulse stroke, the exhaust port and transfer port are uncovered, allowing the exhaust gases to escape into the atmosphere and admitting the fresh charge into the cylinder. At the end of the impulse stroke, the conditions indicated in view (*a*) again exist and the cycle is completed.

17. Combination Two- and Three-Port Engine. Some engines of the two-cycle type operate on both the two-port and the three-port principle, making what is called a **combination two-port** and **three-port engine.** Such an engine is provided with two separate inlet ports, one controlled by a valve as in the two-port engines, and the other opened and closed only by the action of the piston as in the three-port engines. This type of engine is generally so constructed that it may be operated either as a two-port engine or as a three-port engine, or both ports may be used at the same time. The principle of operation of this engine is like that of the engines just described, so that a detailed explanation is not necessary.

FOUR-CYCLE PRINCIPLE

PARTS OF FOUR-CYCLE ENGINE

18. A sectional view of a four-cycle gasoline engine, such as is used on motor boats, is shown in Fig. 4. At *a* is shown the cylinder; at *b*, the cylinder head; at *c*, the piston; at *d*, the piston pin, or wristpin; at *e*, the crank-shaft; at *f*, the crank; at f_1, the crank-pin; at g, the connecting-rod; at *h*, the inlet, or admission, port through which the combustible charge of mixture enters the cylinder; at *i*, the passage through which the charge flows into the port *h*; at *j*, the inlet, or admission, valve, approximately disk-shaped, which closes the inlet passage at

the proper time; at j_1, the valve seat on which the valve j rests when closed; at k, the inlet-valve stem, rigidly attached to and forming part of j; at l, a coiled compression spring that holds the valve j closed, except at such times as it is forcibly opened to admit a charge to the cylinder; at m, the lifting rod, push rod, or thrust rod, that lifts the valve j; and at n, the inlet cam rigidly attached to the inlet cam-shaft o, also called the *half-speed shaft*, or *lay shaft*. As the inlet cam n rotates, its projection, or lobe, bears against the roller at the lower end of the push rod m and lifts the rod, which in turn lifts the inlet valve j. The burned gases escape from the cylinder through the exhaust port p into the passage q and thence to the atmosphere. The exhaust valve r closes the exhaust passage except at such times as it is forcibly opened to release the burned gases. At s is shown the exhaust-valve stem; at t, the exhaust-valve closure spring; at u, the exhaust-valve push rod; at v, the exhaust-valve cam; at w, the exhaust-valve cam-shaft; at x, a compression-relief cock, or petcock, with funnel top; at y, the spark plug; at z, the space for cooling water, which forms a water-jacket to keep the cylinder and adjacent parts from becoming too hot; at a_1, valve-stem guides; at b_1, push-rod guides; and at c_1, the crank-case.

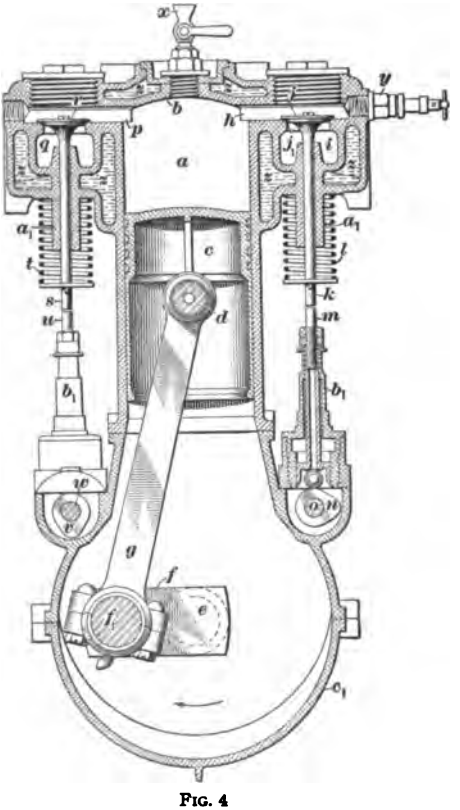


FIG. 4

OPERATION OF FOUR-CYCLE ENGINE

19. As already explained, four separate strokes of the piston, two outward and two inward, are required to complete a cycle in the cylinder of a four-cycle engine. These four strokes are shown diagrammatically in Fig. 5, which presents four cross-sectional views, each showing the cylinder *a* and crank-case *b* cut at right angles to the crank-shaft *c*, exposing to view the piston *d*, the connecting-rod *e*, the inlet and exhaust valves *f* and *g*, and the cams *h* and *i*. These views illustrate the various steps in the operation of the four-cycle type of marine engine and the corresponding positions of the valves. The four-cycle gasoline engine differs in construction from the two-cycle engine principally in that both inlet and exhaust ports open directly into the combustion chamber and are controlled by valves, usually of the so-called poppet type. No deflector, or baffle plate, is needed on the piston face because the inlet and exhaust ports are not opened at the same time, and the crank-case is not made air-tight, for it is not necessary to precompress the charge before admitting it to the cylinder, as there is a separate intake stroke of the piston.

The engine shown in Fig. 5 does not represent any particular make, but illustrates the principle on which all four-cycle, poppet-valve, gasoline engines are operated. If the different events here described and shown are understood, there will be no difficulty in comprehending the operation of any engine of this type.

20. The first stroke in the operation of the four-cycle engine is shown in Fig. 5 (*a*). During this stroke, the piston *d*, following the motion of the crank-shaft *c*, which is being propelled by the force of the preceding explosion, moves downwards as indicated by the arrow. At, or slightly after, the time that the piston starts on this stroke, the inlet valve *f* is opened by means of the cam *h*. As the downward motion of the piston tends to produce a vacuum in the upper part of the cylinder, combustible mixture flows into the cylinder through the inlet port, as shown by the curved arrows, to fill this vacuum,

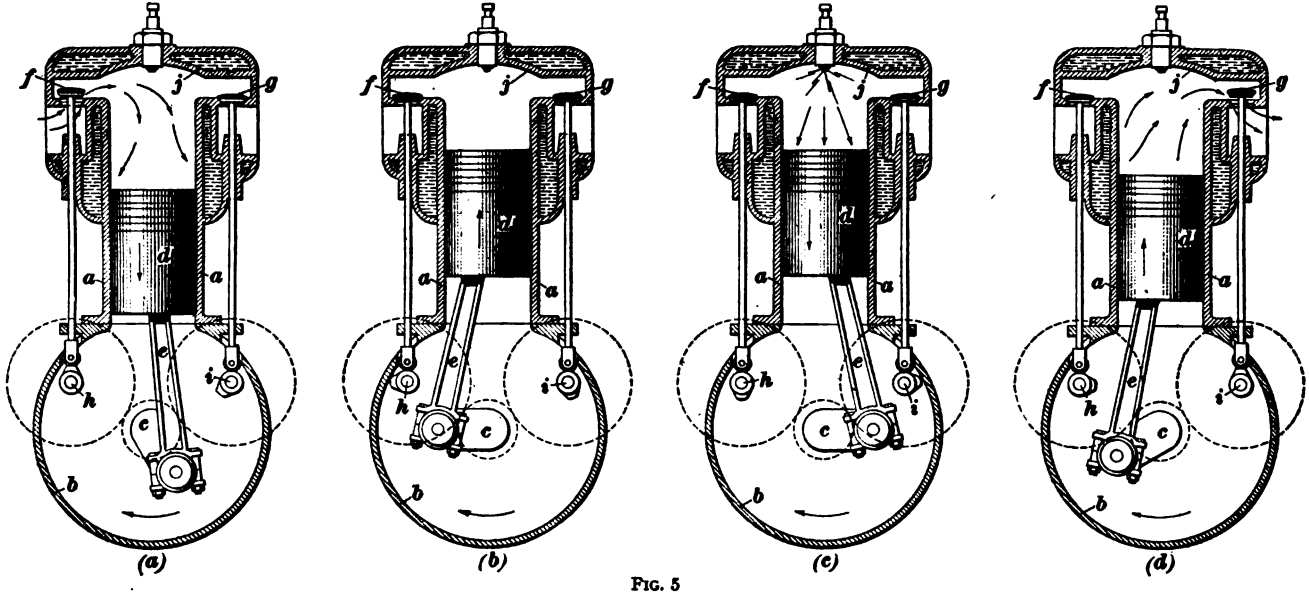


FIG. 5

or, in other words, a charge is drawn into the cylinder. At the end of this stroke, or slightly after, the inlet valve is allowed to close. The exhaust valve *g* is kept closed during this stroke so that none of the entering charge can escape through the exhaust port. Because of the fact that combustible mixture is drawn into the cylinder during this stroke, it is usually called the **suction stroke,** although it is also known as the *charging stroke, admission stroke, inlet stroke,* and *induction stroke.*

21. During the second stroke in the cycle of operations, the piston *d*, still driven by the crank-shaft *c*, moves upwards as shown by the arrow in Fig. 5 (*b*). Both the inlet valve *f* and the exhaust valve *g* are closed during this stroke, so that the combustible mixture that was drawn into the cylinder on the suction stroke, is now compressed into the small space between the top of the piston when it is at the top of its stroke, and the cylinder head *j*. About the time that this stroke, which is called the **compression stroke,** is completed, the charge is ignited by means of an electric spark.

22. The combustible mixture that was drawn into the cylinder on the first stroke of the piston and compressed on the second stroke is completely burned during the third stroke, when the piston is again on its downward movement, as shown in Fig. 5 (*c*). The pressure in the cylinder resulting from the explosion drives the piston downwards and outwards, turning the crank-shaft by means of the connecting-rod and crank. Both valves remain closed from the beginning to nearly the end of this stroke. The exhaust valve *g* is opened by the cam *i* just before the end of the stroke and part of the burned gases escape into the air, so that the pressure in the cylinder falls nearly as low as that of the atmosphere. It is during this downward stroke of the piston that work is done by the charge and a forward impulse is given to the piston, so that it is called the **working stroke.** It is also known as the *impulse stroke, explosion stroke,* or *combustion stroke.*

23. In Fig. 5 (*d*), the piston *d* is shown on the fourth and last stroke of the cycle. During this stroke it moves upwards,

being driven by the crank-shaft, and expels the greater portion of the remaining burned gases from the cylinder through the exhaust port. However, the combustion chamber, between the cylinder head and face of the piston when at the top of its stroke, remains filled with burned gases at the completion of this stroke. The pressure of these residual gases is generally about the same as, or somewhat higher than, that of the external atmosphere. The inlet valve remains closed during this stroke and the exhaust valve remains open until about the time that the piston reaches the end of its stroke. This upward movement of the piston is known as the **exhaust stroke,** and its completion ends the cycle of operations. Following the exhaust stroke, the suction stroke again begins and the series of operations is gone through over and over again in exactly the same manner.

TYPICAL MARINE GASOLINE ENGINES

TWO-CYCLE ENGINES

APPLICATION

24. As a general thing, two-cycle gasoline engines are used on the smaller class of motor boats such as runabouts on lakes and rivers, and small dories on deep water. These engines are usually built with one, two, or three cylinders and develop from 3 to 25 horsepower; although some two-cycle engines are made with four and six cylinders and develop as high as 48 horsepower, or more. However, engines of four cylinders or more are usually of the four-cycle type. Engines having but one or two cylinders are rarely of the four-cycle type because, for the same number of cylinders, two-cycle engines give twice as many power impulses per revolution and consequently run more smoothly. In addition to this, the first cost of small two-cycle engines is less than that of four-cycle motors, and they are usually of simpler construction. Two-cycle motors

will run in either direction, and a large number of these engines are designed so that they may easily be reversed, thus obviating the use of a reversing gear in the propeller shaft.

ARRANGEMENT OF ENGINE CRANKS

25. A two-cylinder, two-cycle, marine engine usually has its cylinders arranged side by side, as in Fig. 6, and the cranks at an angle of 180° apart, or directly opposite each other. In other words, while one piston is moving downwards on its impulse stroke, the other is moving upwards on its compression stroke, so that the explosions alternate, occurring first in one cylinder and then in the other. By this arrangement, an impulse occurs every half revolution and the moving parts are well balanced.

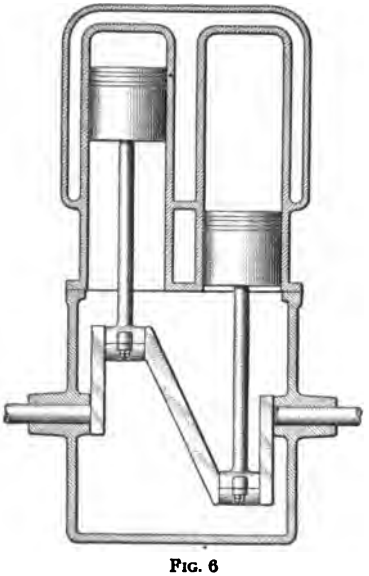


FIG. 6

26. Three-cylinder, two-cycle engines are generally arranged as shown in Fig. 7. The cranks are 120° apart, that is, they are arranged at equal distances around the crank-shaft, so that the impulses occur every third of a revolution. With this arrangement and starting with the first cylinder, an explosion occurs first in cylinder *1*, then in cylinder *3*, and lastly in cylinder *2;* or in other words, the order of firing in such an engine is *1–3–2*.

27. In the four-cylinder, two-cycle engine, all the cylinders are generally arranged in line on one side of the crank-shaft, as shown in Fig. 8. The cranks are arranged 90° apart, hence four impulses occur at equal time intervals for each revolution of the crank-shaft. In order to balance each other and thus

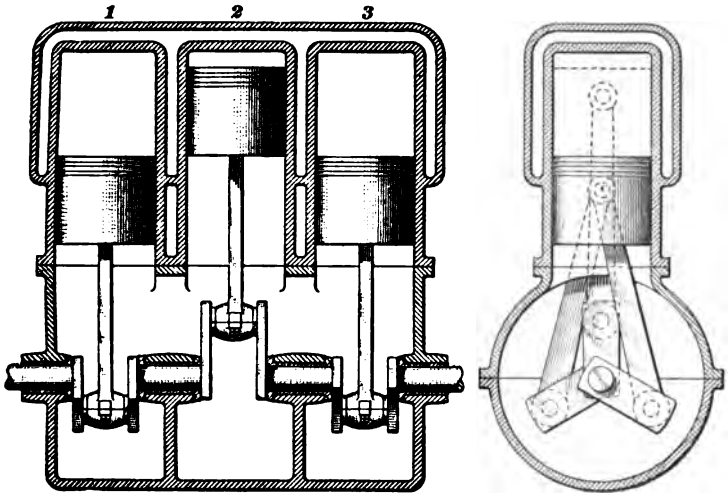


FIG. 7

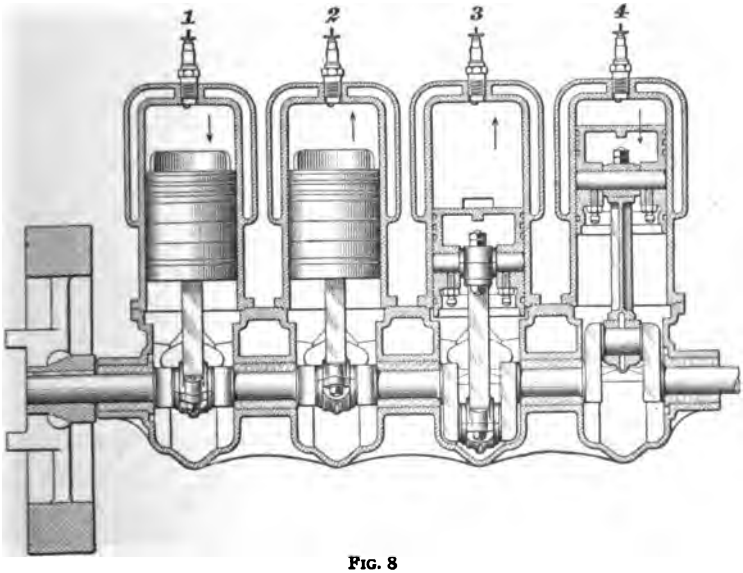


FIG. 8

prevent any great vibration, the cranks are arranged so that cranks *1* and *2* are directly opposite each other and *3* and *4* are directly opposite each other, as shown. Beginning with cylinder *1*, an explosion occurs first in that cylinder, then in cylinder *4*, then in *2*, and finally in *3*; or, in other words, the firing order is *1–4–2–3*. The arrows show the direction in which the pistons are moving, and the numbers at the top

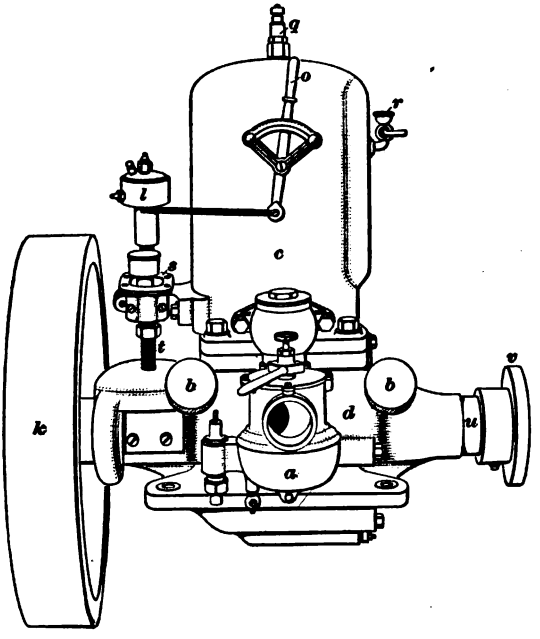


FIG. 9

indicate the usual numbering of the cylinders, *1* being at the front end of the engine and *4* at the rear, or bulkhead, end.

TYPICAL TWO-CYCLE ENGINES

28. Single-Cylinder, Two-Port Engine.—A single-cylinder, two-cycle engine of the two-port type, manufactured by the Gray Motor Company, is illustrated in Figs. 9 and 10. Fig. 9 is an external view of the engine, and Fig. 10 is a longi-

tudinal section through the center, showing the internal construction. The same parts are marked with the same reference letters in the two illustrations.

Fig. 9 shows the inlet side of the engine, with the carbureter *a* for mixing gasoline vapor and air in the proper proportions, and the main bearing oil cups *b*. These parts are not shown in

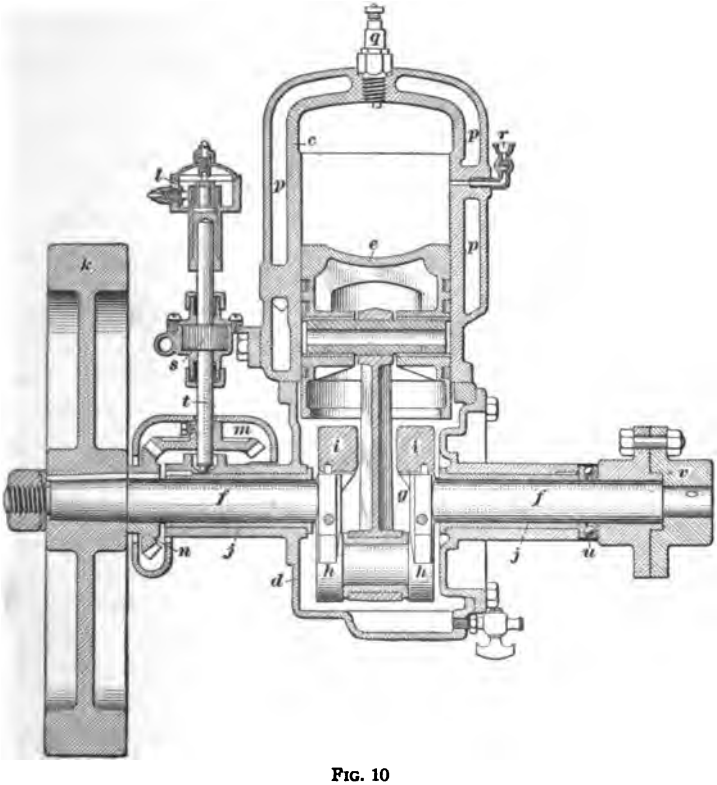


FIG. 10

Fig. 10, because there the front half of the cylinder *c* and crank-case *d* are removed. The exhaust gases pass out of a port located on the opposite side of the cylinder. The piston *e*, Fig. 10, is connected to the crank-shaft *f* by means of the connecting-rod *g* and crank *h*, the crank being provided with counterweights *i* for balancing the engine. The crank-shaft,

which turns in the main bearings *j*, is provided with a heavy flywheel *k* that stores up energy during the impulse stroke and thus carries the engine over the compression stroke. By means of the timer, or commutator, *l*, the time at which the explosion takes place in the cylinder is varied. The timer is driven from the crank-shaft by the bevel gears *m* and *n* and is operated by the hand lever *o*, Fig. 9.

The cylinder proper is surrounded by a jacket space *p*, Fig. 10, through which water is circulated for the purpose of keeping the cylinder walls cool. The combustible mixture is ignited by means of a spark plug *q*, while the compression relief valve and priming cup *r* is used to relieve the compression in the cylinder, when desired, and also for pouring in gasoline, or *priming the cylinder*, in order to start readily. The pump *s*, by means of which the water is forced through the jacket space, is rotated by the timer shaft *t*. The thrust bearing *u* prevents the coupling *v* from being forced endwise by the thrust, or endwise pressure, exerted by the propeller in driving the boat.

29. Single-Cylinder, Three-Port Engine.—In Fig. 11 is shown, in perspective, a single-cylinder, two-cycle engine manufactured by the Ferro Machine and Foundry Company. Part of the cylinder *a* and crank-case *b* is cut away, exposing to view the piston *c*, connecting-rod *d*, and crank *e*. In the position shown, the piston is nearly at the top of its stroke so that the inlet port *f* leading into the crank-case is partly open; the exhaust port *g* is opened only when the piston finishes its downward stroke. The transfer port, on the side of the cylinder not shown, is also closed by the piston.

The timer *h* is driven from the crank-shaft by the bevel gears *i* and *j*. The gears *k* and *l* drive the magneto, or electric generator, *m* which is mostly hidden from view by the cylinder. At *n* is located the water pump used for circulating water through the jacket space *o*. Lubricating oil may be poured through the oil tube *p* into an air-tight reservoir *q* that is cast integral with the crank-case; from this the oil is forced through a pipe, not shown, to the sight-feed distributor *r*, and delivered to the various bearings. The spark plug *s* is located in the

top of the cylinder head *t*, which may be removed, thus giving access to the piston and connecting-rod. The handhole *u* provides a means for reaching inside of the crank-case. It is normally closed by a plug, or cover, that screws into it. Thrust bearings *v* and *w*, located at each side of the crank-case, take

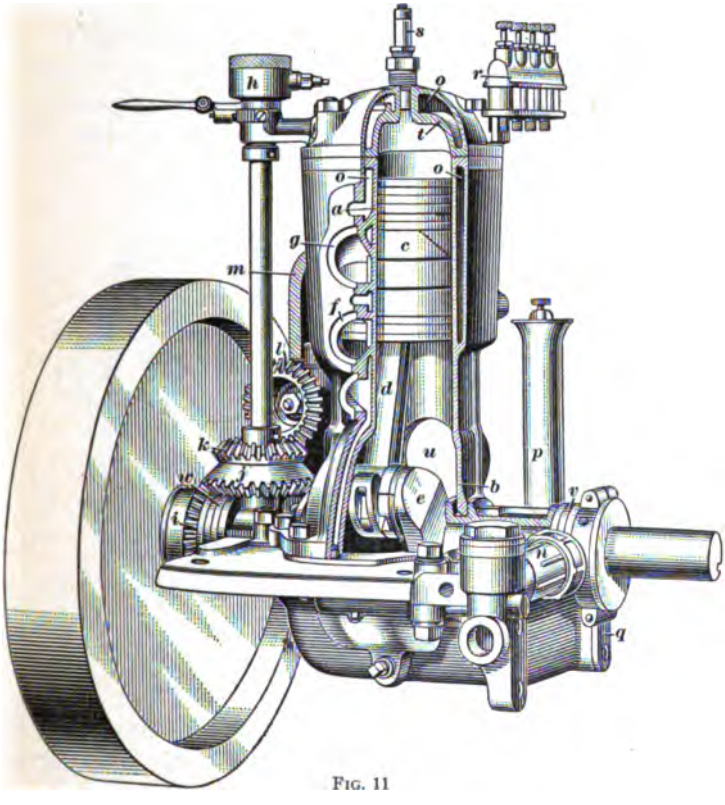


FIG. 11

the thrust of the propeller as it revolves in the water. These bearings consist of three disks, the middle one of which contains the balls. The outside disks turn on the balls, thereby preventing excessive friction when the crank-shaft is forced endwise while rotating.

30. Fig. 12 shows the piston *c*, connecting-rod *d*, and crank *e* of the engine illustrated in Fig. 11, mounted on the

bottom half of the crank-case. The piston and connecting-rod, or the parts that move backwards and forwards are called the *reciprocating parts*. They are connected together by means of the piston pin *a*, which is keyed to the upper end of the connecting-rod and rocks in bearings or bushings in the piston, thus allowing the connecting-rod to swing back and forth as the crank rotates. The connecting-rod is connected to the crank *e* by means of a bearing *b* that fits around a crank-pin joining the two arms of the crank. The crank, crankpin, and crank-shaft *f* are forged from one solid piece of steel. The

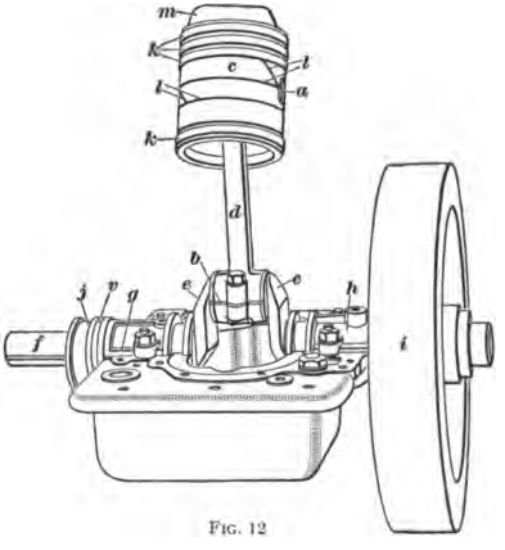


FIG. 12

crank-shaft turns in the bearings *g* and *h*. One thrust bearing is shown at *v*, the other being hidden from view by the flywheel *i*. The eccentric *j* operates the water pump.

31. The piston *c* is of the usual hollow type, and is provided with four piston rings *k*, which make an air-tight joint between the piston and the cylinder walls. Oil grooves *l* provide passages by which the lubricating oil may be distributed over the surface of the piston. The deflector, or baffle plate, *m* guides the entering charge to the combustion chamber and prevents it from escaping by way of the exhaust port.

While all three-port two-cycle engines are not exactly alike, yet, in general, the different parts are for the same purpose and are constructed the same in the different makes.

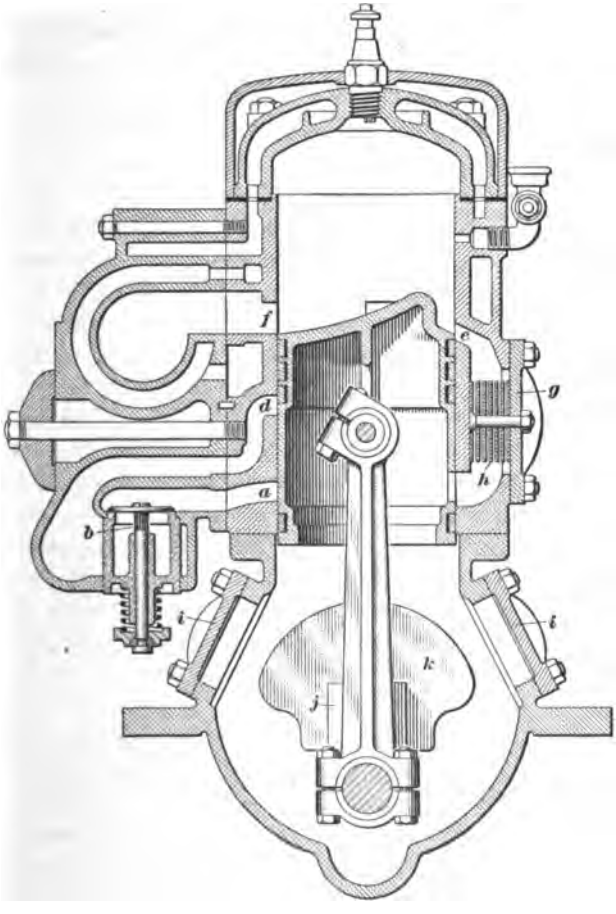


FIG. 13

32. Combination Two- and Three-Port Engine.—A cross-sectional view of a combination two- and three-port engine of the two-cycle type, manufactured by the Gray Motor Company, is shown in Fig. 13. A crank-case inlet port controlled by a valve *b*, such as is provided in the regular two-port

type of engine, is located at *a*, and an inlet port controlled only by the up-and-down movement of the piston *c*, such as is employed in the three-port type, is located at *d*. Port *a* is known as the **second port** and *d* as the **third port.** At *e* is shown the transfer port by means of which the charge travels from the crank-case to the combustion chamber when the piston is in the position shown. The exhaust port *f* is opened in the usual manner by the piston on its downward stoke.

The valve *b* that controls the second port *a* allows the combustible mixture to enter the crank-case when this port is opened on the upward stroke of the piston, but it prevents the charge from flowing back into the intake pipe and carbureter when the piston descends. The port *d* is placed so high up in the cylinder wall that the piston covers it as soon as the downward stroke is begun, and thus prevents the gas from escaping by that passage.

The by-pass plate *g* carries a device *h* that prevents the burning gases in the combustion chamber from blowing back into the crank-case on the impulse stroke. Such a blowing back of the gases would cause an explosion of the gases in the crank-case, which would be extremely undesirable. The interior of the crank-case may be reached by removing the handhole covers *i*. The crank *j* is provided with counterweights *k* for the purpose of balancing the engine and causing smooth running.

33. The advantage claimed for the combination two- and three-port engine is that when running at slow speeds the second port insures reliability and an economical fuel mixture, while at high speeds the third port makes possible the development of the most power obtainable. It is usually true that at low speeds a two-port engine will develop greater power than a three-port engine but that the latter will develop a little more power at high speeds; hence, it has been thought that by combining the two, the most economical conditions at both high and low speeds might be obtained.

The engine illustrated in Fig. 13 is so constructed that either the second port or third port may be made inoperative

at will, thus converting the motor into a three-port engine or a two-port engine, or, it may be run as a combination two- and three-port engine.

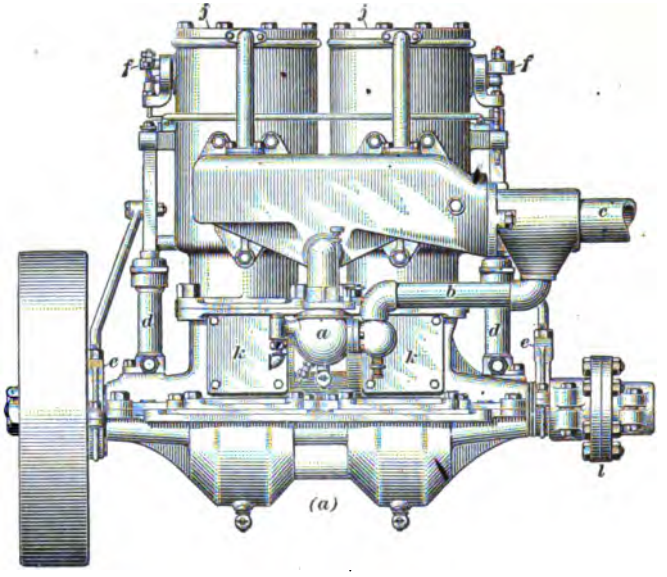
34. Two-Cylinder, Two-Cycle Engines.—Marine gasoline engines having two or more cylinders operate on exactly the same principle as single-cylinder engines. Each cylinder has its own cycle of operations, which are usually timed so that the explosions in the different cylinders will occur at regular intervals. Usually one carbureter supplies the fuel to all the cylinders, although some two-cycle engines having three or more cylinders have a separate carbureter for each cylinder in order to insure a full charge.

Two-cylinder engines may have their cylinders cast separately or in pairs. When cast separately, either cylinder may be unbolted and removed from the crank-case independently of the other; but when cast in pairs they form one piece. When all of the cylinders of an engine are made in one casting they are said to be cast *in block*, or *en bloc*.

35. An example of a two-cylinder, two-cycle marine engine with its cylinders cast separately is given in Fig. 14, which shows an external view (*a*) and a cross-section (*b*) of the type "K," Fairbanks-Morse engine. This engine is of the three-port type but in construction it is very similar to the single-cylinder, two-port engine previously described.

One carbureter *a* supplies fuel to both cylinders. To help vaporize the fuel, hot air is carried by the pipe *b* from the exhaust pipe *c* to the carbureter. Each cylinder is provided with a water pump *d*, which is of the plunger type and is operated by an eccentric *e* on the crank-shaft; the same eccentric operates an igniter *f* on each cylinder. This igniter creates a spark inside the combustion chamber, thus igniting the charge at the proper time.

A centrifugal oil ring *g*, view (*b*), conducts lubricating oil through a duct *h* to the crank-pin. A screen *i* in the transfer port prevents a flame from passing back into the crank-case and causing an explosion. The cylinder heads *j* and the hand-



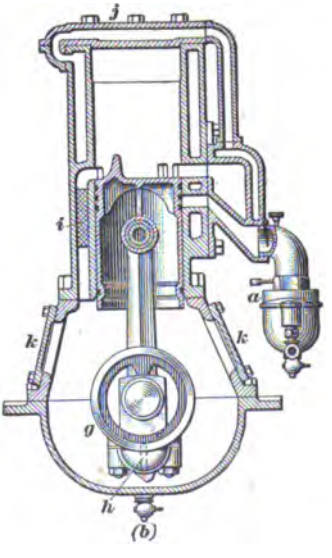


FIG. 14

hole plates *k* are bolted on; they are therefore removable, providing ready access to the interior of the cylinders.

36. The crank-case and crank-shaft of the engine illustrated in Fig. 14 are shown in Fig. 15. In view (*a*), the upper and lower halves of the crank-case are separated, exposing to view the three crank-shaft bearings *a*, *b*, and *c*. When assembled,

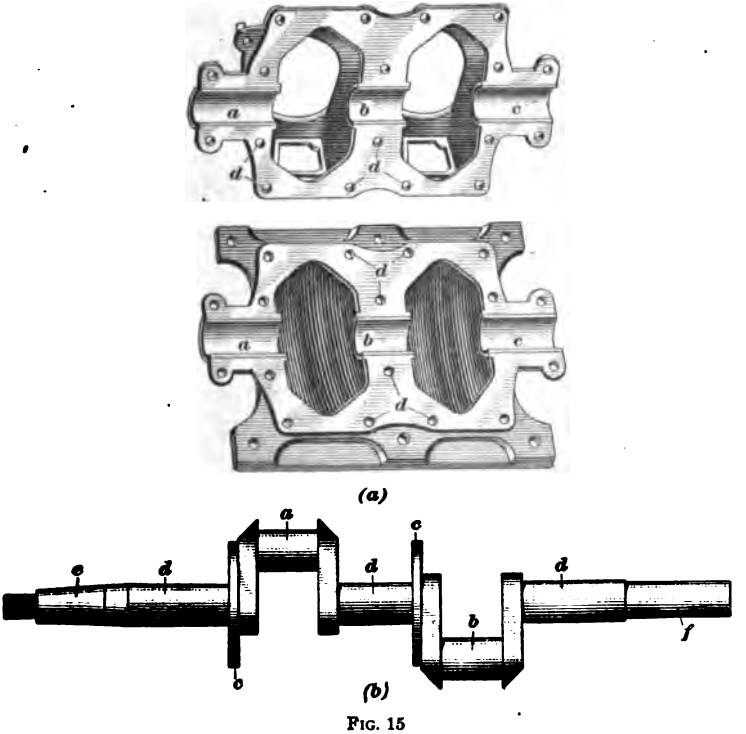


FIG. 15

the two parts are bolted together through the holes *d*. In view (*b*) is shown the crank-shaft. The cranks *a* and *b* are arranged directly opposite each other and carry the centrifugal oil rings *c*. When placed in the crank-case, the journals *d* rotate in the main bearings *a*, *b*, and *c*, view (*a*). The flywheel is secured to the end *e* and the propeller shaft to the end *f* by means of a coupling *l*, Fig. 14.

The crank-shaft shown in Fig. 15 is called a **three-bearing crank-shaft** because it turns on three bearings. Sometimes, as in the case of cylinders cast in pairs, two-cylinder crank-shafts have only the two end bearings, the middle bearing being eliminated in order to shorten the engine and thus make it more compact.

37. In Fig. 16 is shown an external view of the Northwestern, two-cylinder, two-cycle engine with the cylinders cast in one piece, or in block. A water-jacket surrounds both

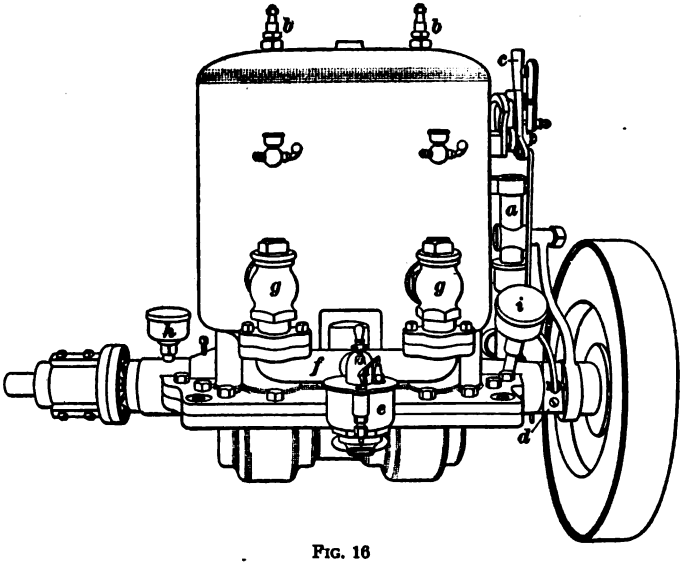


FIG. 16

cylinders, water being forced through it by means of the plunger pump *a*. Each cylinder is provided with a spark plug *b*; the time at which the spark will occur is varied, or controlled by the lever *c* that operates a timer *d* on the crank-shaft. The carbureter *e* supplies fuel to both cylinders through the intake manifold *f* and intake pipes *g*. The oil cups *h* and *i* supply oil to the crank-shaft bearings.

This style of engine has a very compact appearance and the advantage claimed for it is that the block casting insures absolute alinement of all parts at all times.

38. Three-Cylinder, Two-Cycle Engine.—As a rule, three-cylinder, two-cycle engines have their cylinders cast separately. An engine of this type, operating on the combination two-port and three-port principle, is illustrated in Fig. 17 (*a*), which shows a perspective view of a three-cylinder engine manufactured by the S. R. Manufacturing Company. The combination inlet and exhaust manifold, removed from the engine, is shown in (*b*).

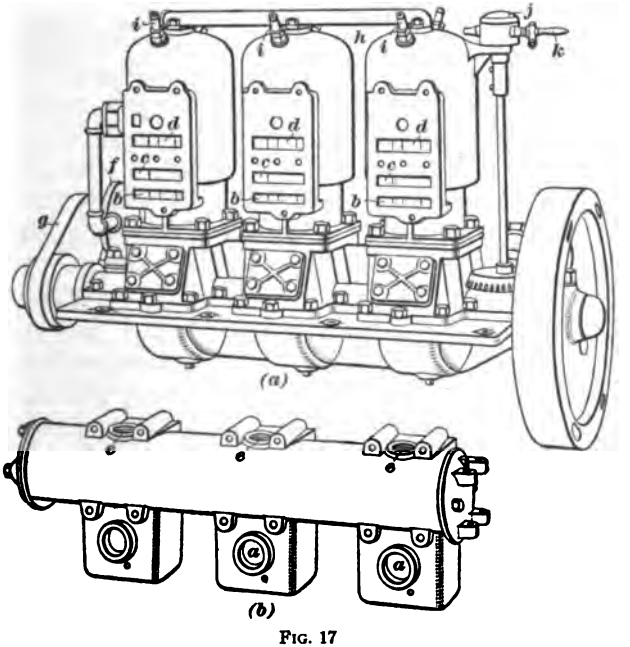


FIG. 17

The gas enters the manifold through the openings *a* and passes into the cylinders through the inlet ports *b* and *c*. The burned gases leave the cylinders through the exhaust ports *d* and escape from the manifold through the openings *e*. Water circulation is by means of a gear-pump *f* driven from the crank-shaft by spur gears enclosed in the casing *g*. The jacket spaces are connected by the pipe *h*.

This engine is provided with a double ignition system so that, at the time of ignition, a spark will be produced simul-

taneously at both spark plugs *i* in a cylinder. The time of ignition in each cylinder can be varied by the timer *j*, which is operated by the handle *k*. The advantage of this system is that when the charge is thus ignited at two points at the same time, a quicker and more complete combustion takes place with a consequent increase in power.

39. Cross-sectional views of one of the cylinders of the engine shown in Fig. 17 are given in Fig. 18, the same parts being lettered the same as in the previous illustration. The inlet ports are shown at *b* and *c*. At *b*, the valve *l* prevents gas from being blown back into the manifold on the working stroke, while port *c* is controlled only by the movement of the piston. The exhaust port is shown at *d*. Each port is composed of a number of slots located at intervals around the cylinder in order to obtain a large port area. The transfer passage *m* is located on the opposite side of the cylinder from the manifold. The spark plugs are shown at *i* and the water-jacket spaces at *n*. Besides passing around the cylinder, the water also flows around the exhaust manifold, thereby cooling the exhaust gases.

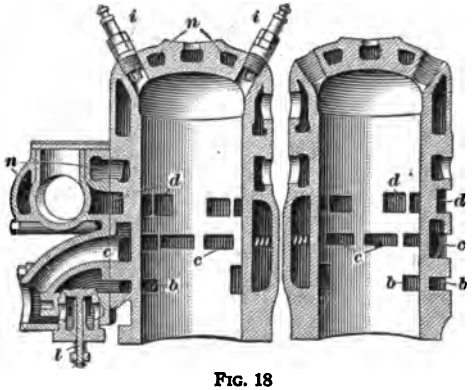


FIG. 18

FOUR-CYCLE ENGINES

APPLICATION

40. Four-cycle marine engines are usually of the vertical type and, in appearance, are very similar to the two-cycle engines. One exception to this, however, is the so-called **V**-type engine, which has one-half of the cylinders located on each side of the crank-shaft and the two rows placed at an

angle of 90° or a little less to each other. The V-type engine is usually high-powered and built with at least six or eight cylinders. Four-cycle engines of the vertical type are found in practically all of the four- and six-cylinder types where high speed and power are required. Two- and three-cylinder four-cycle engines are used less frequently and single-cylinder engines are scarcely used at all.

ARRANGEMENT OF ENGINE CRANKS

41. Two-cylinder four-cycle marine engines have their cranks arranged side by side, as shown at *a*, Fig. 19, so that the pistons move in unison; that is, they move up or down at the same time. By having the cranks arranged in this manner, an explosion occurs in one of the cylinders for each revolution of the crank-shaft, or each time the pistons move downwards, so that the power impulses occur at regular time intervals of one revolution apart. A uniform application of power to the crank-shaft is thus obtained, although such an engine is hard to balance and will cause vibrations.

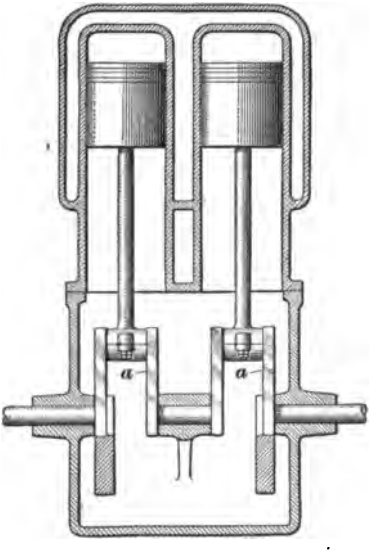


FIG. 19

42. Three-cylinder, four-cycle engines have their cranks arranged at equal intervals around the crank-shaft, or 120° apart, as shown in Fig. 7. On account of the difficulty in balancing the moving parts, this type of engine is not used extensively.

The cranks of four-cylinder, four-cycle engines are arranged in pairs, the two middle cranks forming one pair, and the two end ones forming the other. The pairs are located on opposite

sides of the crank-shaft, as shown in Fig. 20; hence, as the two middle pistons move upwards, the two end ones move downwards, and vice versa. With this arrangement of cranks, there are two different orders in which the explosions can occur in the cylinders. The *order of explosions* may be either *1–3–4–2* or *1–2–4–3*. In the first case an explosion first takes place in cylinder *1*, then in *3*, then in *4*, and finally in *2*. In the second case an explosion takes place first in cylinder *1*, then in *2*, then in *4*, and finally in *3*. With either of these orders a power impulse occurs in one of the cylinders every half revolu-

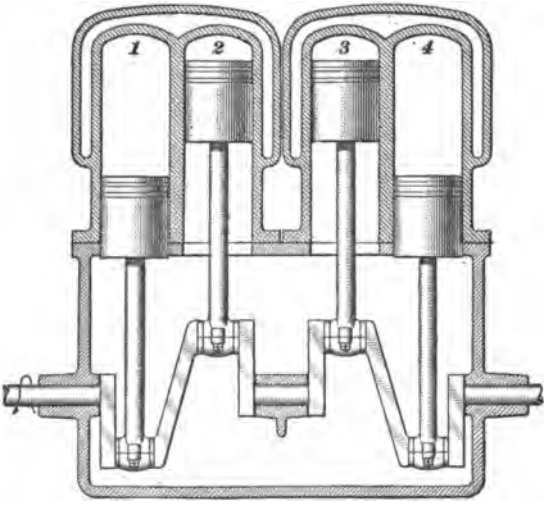


FIG. 20

tion of the crank-shaft. As the two middle pistons move in unison and in a direction opposite from that of the two end pistons, the whole system of moving parts is well-balanced.

43. Six-cylinder, four-cycle, marine engines have their cranks arranged in pairs, each pair consisting of two cranks located on the same side of the crank-shaft and in the same plane. The usual arrangement is shown in Fig. 21. The cranks of cylinders *1* and *6* form a pair, those of cylinders *2* and *5* form a pair, and those of cylinders *3* and *4* form a pair. The pairs are located at equal intervals around the crank-shaft,

that is, at an angle of 120° with one another. The two pistons of each pair move in unison.

The impulses in the cylinders of a six-cylinder, four-cycle engine occur at intervals of one-third of a revolution; therefore,

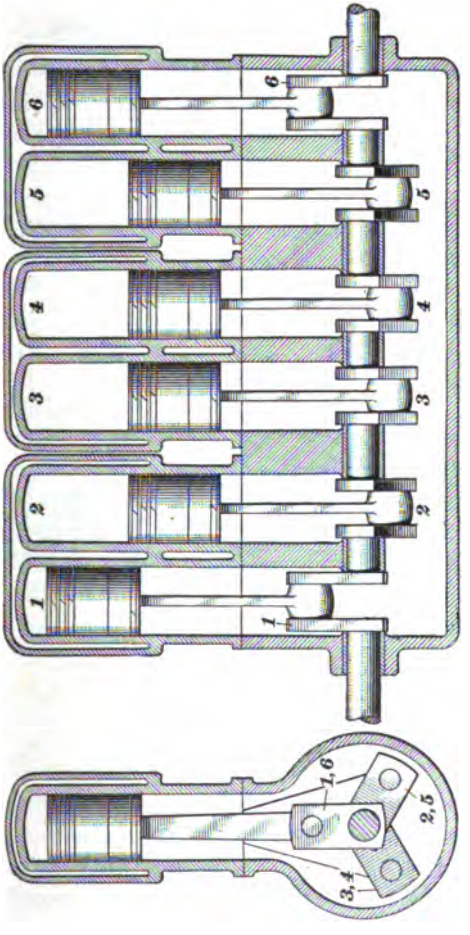


FIG. 21

there are three impulses per revolution. Considering the cylinders as being in pairs corresponding to the three pairs of cranks, the explosions first occur in one cylinder of each pair and then in the remaining cylinders of each pair in the same

order. There are four possible firing orders with the arrangement shown in Fig. 21 as follows: *1–3–2–6–4–5*, *1–3–5–6–4–2*, *1–4–5–6–3–2*, and *1–4–2–6–3–5*.

TYPICAL FOUR-CYCLE ENGINES

44. Two-Cylinder, Four-Cycle Engine.—The intake side of the Sterling 20-horsepower engine, which is a typical two-cylinder, four-cycle marine engine, is shown in Fig. 22.

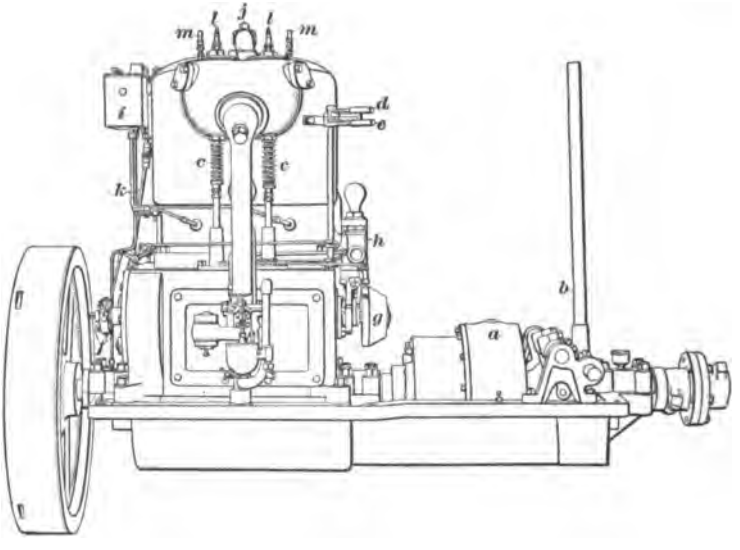


FIG. 22

This engine is an example of what is called the *unit power-plant* type of construction, so called because the engine and reverse mechanism are mounted on the same base. The reverse mechanism *a* is for the purpose of reversing the propeller while the engine runs in one continuous direction, or of disconnecting the engine from the propeller shaft. It is operated by means of the lever *b*. The cylinders of the engine are cast in block, with the inlet valves on one side and the exhaust valves on the other, forming what is called a **T**-*head motor*. The inlet valve springs are shown at *c*.

The speed and power of the engine are controlled by the hand levers *d* and *e*. One of these levers is connected to the spark timer *f* and regulates the time of ignition; the other is connected to the carbureter throttle valve. Within certain limits the speed of the engine is also regulated by a centrifugal governor *g*, which is driven by one of the cam-shafts. The governor is connected to the throttle valve in such a way that it maintains a constant, or nearly constant, speed under variable loads and with the throttle hand lever in any one position.

The cooling water pump *h* is of the plunger type and forces water into the jacket space at the bottom of the cylinder. The water flows out at *j* and thence by a pipe to the exhaust manifold, which is located on the side of the engine not shown. The oil pump *i* is a mechanical force-feed oiler and is driven from the cam-shaft through the vertical shaft *k*. The spark plugs are shown at *l* and the priming cups at *m*.

45. Four-Cylinder, Four-Cycle Engine.—Four-cylinder, marine, gasoline engines may have their cylinders cast separately, in pairs, or in block. An engine of this type having its cylinders cast separately, is shown in Figs. 23 and 24, which illustrate one model of the Speedway marine engine. Fig. 23 shows a side view and Fig. 24, an end view, like parts in the two views being lettered the same. This engine is another example of the unit power-plant type of construction. The construction of the cylinders differs from that of the cylinders in Fig. 22 in that the inlet and exhaust valves are located on the same side of the cylinder. This forms what is known as an ***L-head motor***.

46. Both illustrations should be referred to in connection with the following. The valves are operated from a single cam-shaft *a* that is driven at one-half the crank-shaft speed through the spur gears *b* and *c*. The inlet valves *d* are opened against the force of their springs by the rocker-arms *e*, which are operated by the cams *f* and the push rods *g*. The exhaust valves *h* are opened directly by the push rods *i* and the cams *j*. In both cases the valves are closed by their springs which surround their stems. The carbureter *k* is located on the same

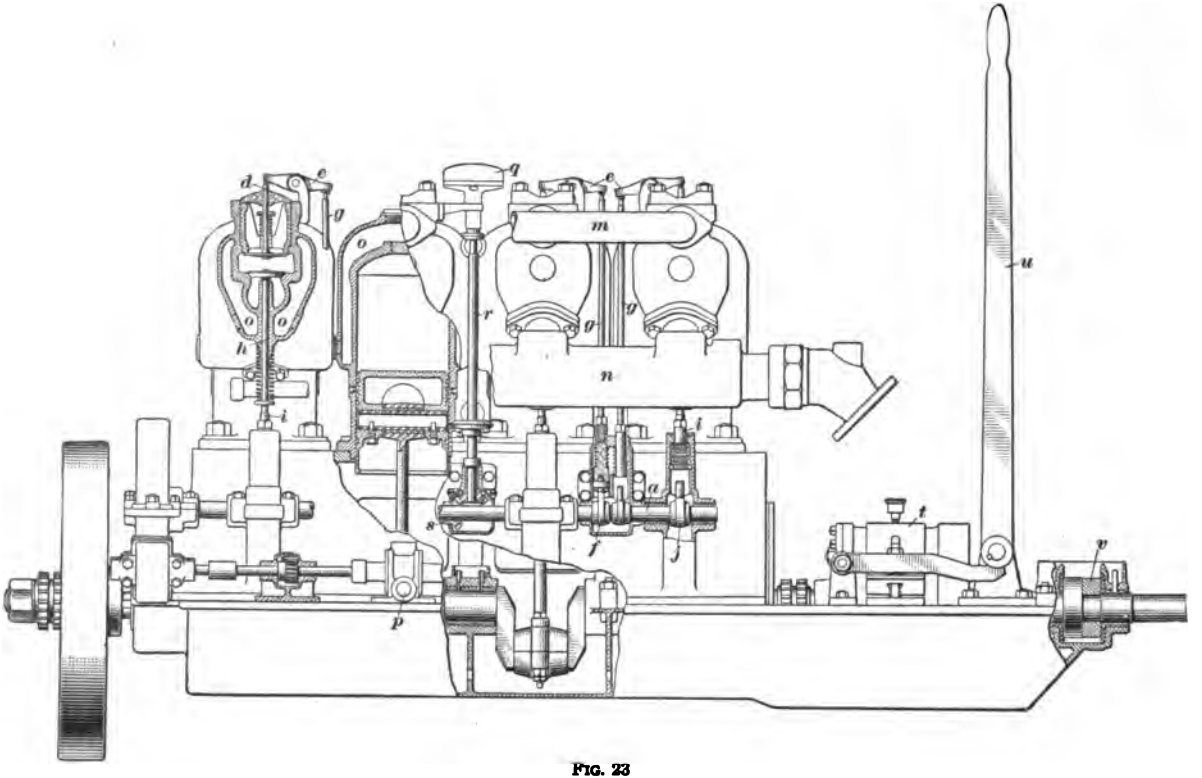


FIG. 23

side of the engine as the valves, and the mixture is carried to the various cylinders through the pipe *l* and the manifold *m*. The exhaust gases escape through the exhaust manifold *n*. The cylinders and exhaust manifold are surrounded by the jacket

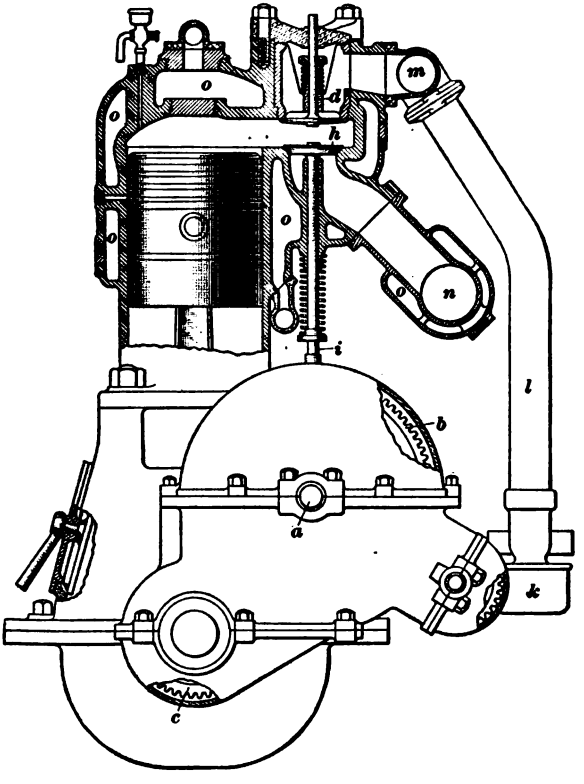


FIG. 24

spaces *o*, through which cooling water is forced by a pump *p*, driven by a separate shaft, which is geared to the cam-shaft. The spark timer is located at *q*, and is driven by the vertical shaft *r*, which, in turn is driven from the cam-shaft through the bevel gears *s*. The reversing gear *t* is operated by the lever *u* and the coupling *v* is for the purpose of connecting the engine shaft and the propeller shaft.

47. Six-Cylinder, Four-Cycle Engine.—A typical six-cylinder, four-cycle marine engine with its cylinders cast separately is shown in Fig. 25, which is an intake side view of a type B Van Blerck engine. The reverse mechanism *a* is mounted on the engine base *b*. A battery and the magneto *c* furnish current for the ignition system, and the lubricating oil is pumped from the crank-case to the various bearings by the force-feed oiler *d*. Hot-air is conducted from around the exhaust pipe to the carbureter *e* by means of the pipe *f*, and a combination timer and distributor *g* conducts the battery current to the various spark plugs. The engine is of the T-head type; that is, the inlet valves are located on one side of the cylinders and the exhaust valves on the other. The inlet valve springs are shown at *h*.

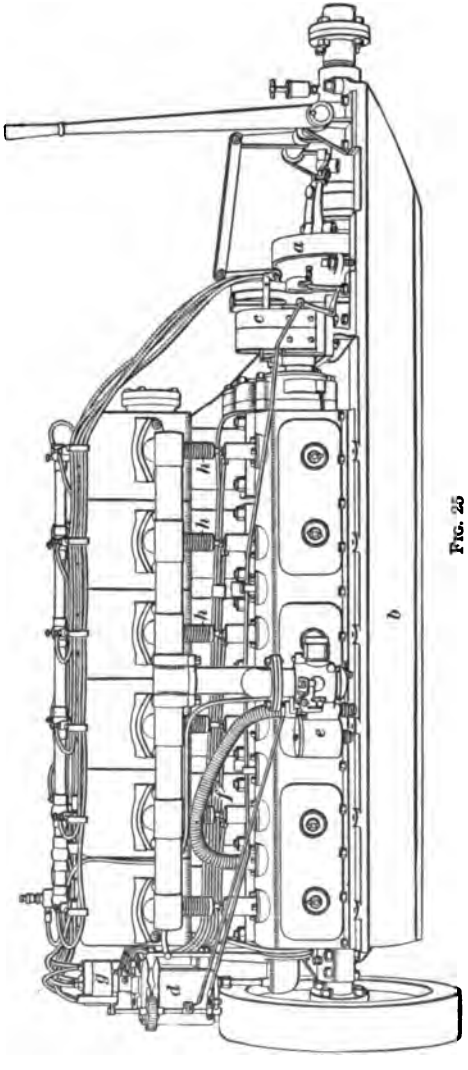


FIG. 25

48. The engine shown in Fig. 25 is made to run at from 500 to 700 revolutions per minute and is especially serviceable for use in cruisers

and work boats. Six-cylinder engines for fast runabouts and light, speedy pleasure boats are made to run at much higher speeds. Marine gasoline engines of the four-cycle type are also made with eight and twelve cylinders where very high speed or power is desired.

MARINE ENGINE AUXILIARIES

MARINE-ENGINE COOLING

WATER-CIRCULATING SYSTEMS

49. Exhaust Fittings.—Marine engines are cooled by the circulation of water through the water-jacket of the engine

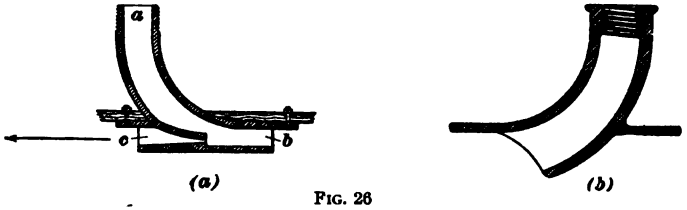


FIG. 26

cylinder. A pump attached to the engine draws water through the bottom of the boat, sends it to the engine, and finally discharges it overboard, usually by way of the exhaust pipe, which is sometimes led under water, discharging through a special fitting, one form of which is shown in Fig. 26 (*a*).

The exhaust enters the fitting at *a* and leaves at *b*, under the water, the boat moving in the direction of the arrow. On account of the velocity of the boat, water rushes into the opening *c*, through the gradually reducing passage, into the exhaust pipe, and out with the exhaust at *b*. This arrangement tends to increase the velocity of the exhaust and reduce the back pressure on the engine. Another form of exhaust nozzle is shown in (*b*). This form resembles that shown in (*a*), except that the passage *c* is omitted. Such devices are known as *under-water exhausts*, or *submerged exhausts*.

50. Water-Cooling Systems.—The type of water-cooling systems most commonly used on marine gasoline engines is illustrated in Fig. 27, which shows a portion of the piping for a single-cylinder engine. The cylinder *a* is surrounded with a jacket *b* that is usually cast integral with the cylinder. A water space *c* is thus formed, through which cold water from overboard is circulated by means of any kind of a water pump *d* that will keep the water in circulation. This pump is usually located alongside of or at one end of the engine, and is connected to the water-jacket *c* by means of a pipe *e*. The pump is driven from the crank-shaft of the engine. When the engine is in operation, the cooling water is pumped from overboard through the pipes *f* and *e* to the water space *c*. The pressure from the pump forces the water up and around the cylinder wall and out at the outlet *g*. From *g*, a portion of the water usually passes into the exhaust pipe and escapes with the exhaust gases, and the remainder flows overboard. Sometimes all of the cooling water escapes with the exhaust gases, thus helping to cool them. A continuous circulation of cooling water is kept up during the entire time that the engine is running. The cylinder walls are kept cool by the water and the lubricating oil is prevented from being burned in the cylinder.

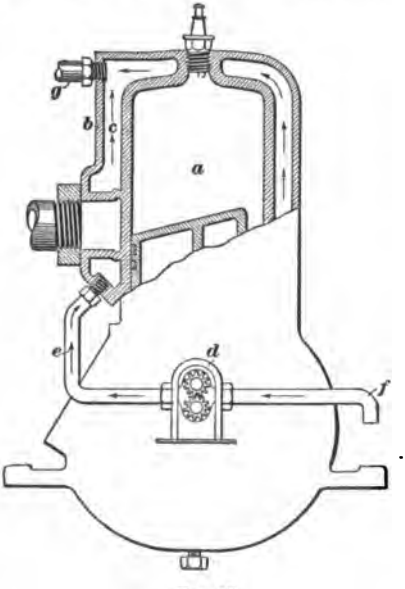


FIG. 27

A cooling system of this type may be applied to a multiple-cylinder engine by connecting the water passages of the various cylinders with pipes, and forcing the water from one cylinder to another before allowing it to escape overboard.

51. A unique water-cooling system for a single-cylinder, marine, gasoline engine is shown in Fig. 28, which shows the water-circulating system for the Ferro engine. Part of the cylinder wall *a* is cut away, exposing to view the water-jacket *b* and the passage *c* through which the water circulates. Water is drawn from overboard through the pipe *d* and forced by the

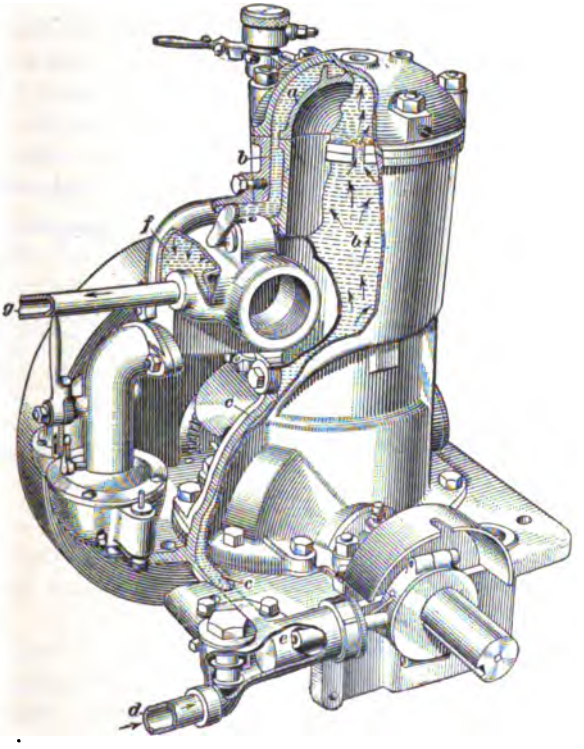


FIG. 28

pump *e* through the passage *c* into the water-jacket space *b*. From this space it flows into the jacket space *f*, around the exhaust manifold, and then overboard by way of the pipe *g*.

By means of this system, cold water is constantly kept in contact with the cylinder walls, preventing them from becoming overheated and damaged from the heat of the repeated explosions, and from burning the lubricating oil within the cylinder.

CIRCULATING PUMPS

52. Plunger Pump.—A type of water-circulating pump used extensively on gasoline marine engines, and especially on the smaller sizes, is the plunger pump. In Fig. 29 is shown a longitudinal section of the pump used on the engine in Fig. 11. In this pump, the water is forced through the cooling system by means of the hollow piston plunger *a*, which is driven backwards and forwards in the barrel *b* by means of the eccentric *c* surrounding the crank-shaft *d*. Check-valves *e* and *f* prevent the water from flowing back into the inlet pipe *g*. As the plunger moves forwards toward the crank-shaft, the suction thereby created lifts the check-valve *e* from its seat and draws

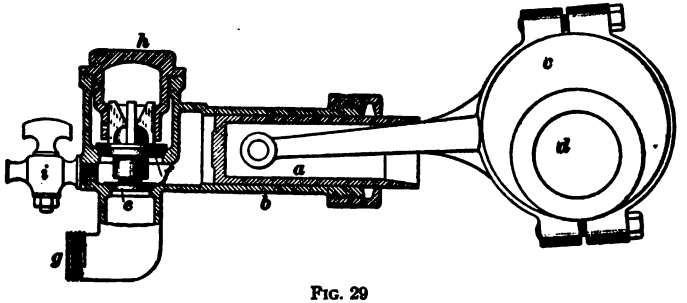


FIG. 29

water into the barrel. On its return stroke, the plunger forces the water through the check-valve *f* into the passage that leads to the cylinder jacket.

During the backward stroke of the plunger the check-valve *e* prevents the water from escaping back into the pipe *g*; and during the forward stroke, the valve *f* prevents the water from being drawn from the jacket space back into the pump. The check-valves may be taken out by removing the plug *h*. The cock *i* is for the purpose of draining the water from the pump barrel.

53. Centrifugal Pump.—Another type of water-circulating pump used quite extensively is the centrifugal pump, which operates on the principle shown in Fig. 30. In this pump the only moving part is a bronze or aluminum disk *a*, keyed on

a shaft *b*, and on one face are cast blades *c*, which may be radial, as shown, or bent backwards. The shaft carries the disk *a* at one end, and works through a stuffingbox to prevent leakage. The water enters the pump through an opening indicated by the dotted circle *d*. This inlet is on the side of the pump toward the observer, and, therefore, cannot be seen in the illustration. As the water enters the pump, it meets the blades *c* and is carried around and thrown outwards by centrifugal force, being expelled at *e*, provided the passage outside the pump is open. It is not necessary that either the disk or the blades have a water-tight fit in the casing, because the pump simply establishes a difference in pressure between the points *d* and *e*, but does not positively force the water. Consequently, if the flow is obstructed for any reason, the pump can still be revolved without injury to itself. Moreover, this type of pump does not lose its efficiency through wear. The pump is run at quite a high speed, generally about twice the speed of the engine; and if the resistance to circulation is not too great, it will throw quite a large stream of water. It is usually mounted on the crank-case of the engine and geared to the cam-shaft or to the two-to-one pinion.

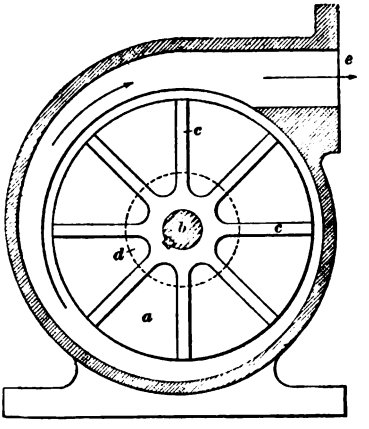


FIG. 30

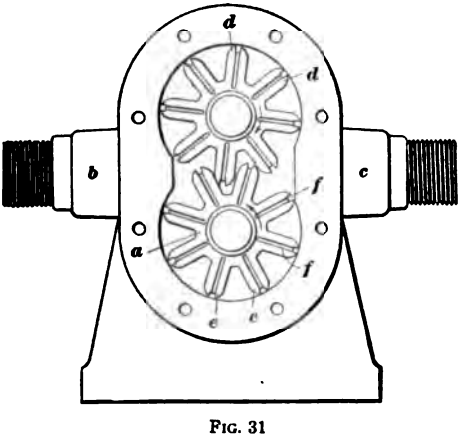


FIG. 31

54. Gear-Pump.—A type of pump used to some extent for circulating purposes is the gear-pump shown in Fig. 31. It operates equally well in either direction. One of the two gear-shaped pump members *a* is driven by a shaft and rotates the other with it. If the direction of rotation is that shown by the arrows, the water will enter at *b*, and pass out at *c*, being carried around by the outer teeth *d* and *e* and expelled as the teeth come together. The particular pump shown has grooves *f* in the sides and tips of the teeth, which, it is claimed, prevent to a large extent leakage past the teeth, and thereby increase considerably the efficiency of the pump.

MISCELLANEOUS AUXILIARIES

MUFFLERS

55. A muffler, or silencer, is a device used for deadening the noise of the exhaust gases as they escape into the atmosphere at the end of the working stroke of a gasoline engine. The sound is deadened, or muffled, by leading the gases into a chamber where they are cooled somewhat and allowed to expand so that the pressure at which they enter the air will be reduced. Mufflers constructed for marine engines are known as the wet and jacketed mufflers or the construction may represent a combination of both of these types.

In the *jacketed muffler*, water from the cylinder water-jacket outlet is allowed to circulate around the outside of the muffler, to assist in cooling the gases and thereby reducing their volume. The *wet muffler* is one in which all or a part of the exhaust water from the water-jacket is discharged into the engine exhaust, where it is turned into steam, cools the exhaust gases, and combines with them, increasing their density and sluggishness, and thereby muffling the exhaust. The water from a jacketed muffler may be diverted into the exhaust itself, to further reduce the sound of the exhaust, this being the combination system already mentioned. The wet and combination mufflers are the most common types used in marine service.

56. A typical marine engine muffler is illustrated in Fig. 32, which is a sectional view of the Standard muffler showing the interior arrangement.

This muffler is comprised of three expansion chambers *a*, *b*, and *c*, separated by two sets of conical baffle plates *d* and *e*. The exhaust gases and waste water from the cooling system enter the muffler by the inlet opening *f* and pass out through the outlet *g*, which is placed low in the outlet head to provide a means of escape for any surplus water that may accumulate. A part of the gases entering the muffler passes directly into the chamber *a*, while the remainder passes through the axial tube *h*, some escaping by means of the holes *i* into the middle chamber *b* and some going clear through the tube and out of the nozzle *j*.

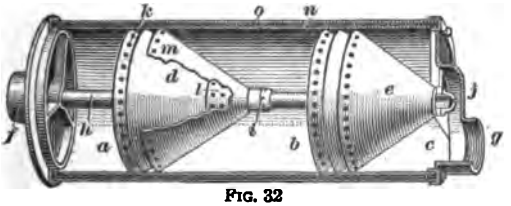


FIG. 32

The cones that separate the expansion chambers are perforated at top and bottom, so that the gases that enter the chamber *a* pass through the holes *k* in the first cone, *l* in the second cone, and *m* in the last, into the chamber *b*. The gas passing out of the nozzle *j* at high velocity creates a vacuum in the chamber *c*, so that the gases move rapidly into it from the second chamber *b* by way of the holes in the conical baffle plates *e*. This rapid forward movement of the exhaust gases through the first and second chambers to the third, causes a sudden expansion, removing the heat from the gas and reducing the pressure in the muffler, so that the gases escape into the atmosphere without any noise.

The walls of the muffler consist of an inner layer *n* of heavy material and an outer metal covering *o*, separated by a layer of asbestos, so as to prevent metallic sound from the gas impinging against the walls. To secure best results the asbestos used should be wire woven.

This muffler, shown in Fig. 32, is designed for use where the water is run into the exhaust pipe near the engine. Some mufflers are made with a separate water inlet located in the same end that the gas inlet opens into.

57. Two types of marine engine mufflers in which the water mixes with the exhaust gases are shown in Fig. 33. In view (*a*) is shown the Thermex silencer consisting of a spherical shell *a*, into which the exhaust gas passes by way of the inlet *b* and the water by way of the opening *c*. The gases expand in the shell, and become cooled by contact with the water, after which they enter the exhaust outlet at *d* and pass out at the opening *e*. The opening for the exhaust outlet in the center of the chamber is adjustable by screwing in or out the long nipple *f*. The larger portion of the water passes out of the drain *g*, a small portion being taken out with the exhaust gas. The location of the exhaust inlet with the water inlet directly in the path of the entering gases gives the water and gases a circular motion, allowing the gas to cool and expand and reducing the pressure.

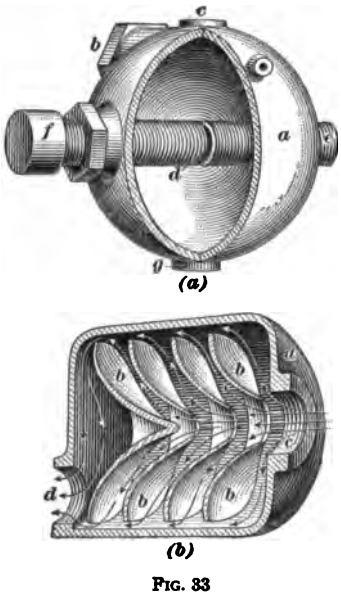


FIG. 33

58. In view (*b*) is shown the Gray muffler, which consists of the cylinder *a* fitted with deflecting plates *b*. The exhaust gases and circulating water enter the cylinder at *c* and escape by way of the opening *d*. Part of the exhaust gases passes through the holes in the center of the baffle plates and a portion passes between the edges of the plates and the wall of the muffler, as shown by the arrows. The deflecting plates break up the force of the incoming gases and allow them to expand, thus reducing the pressure and allowing the exhaust to pass into the atmosphere without noise.

59. The **underwater, or submerged, exhaust** is a device used on a large number of boats in place of a muffler, for the purpose of muffling the noise of the engine exhaust and at the same time carrying the gases under the water. It consists of a special outlet fitting placed from 3 to 5 inches under the water-line, as far aft as possible, and so arranged that the gases will escape in a direction opposite to that in which the boat is moving.

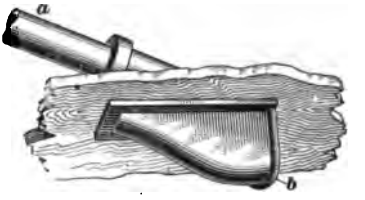
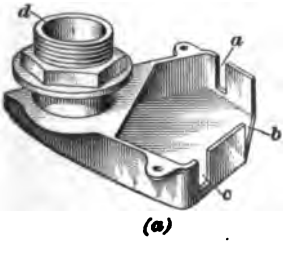


FIG. 34

One type of underwater exhaust is shown fitted to the side planking in Fig. 34. The exhaust gases from the engine enter through the pipe *a* and escape into the water by way of the outlet *b*. The suction of the water as the boat moves ahead serves to draw the gases out and to relieve any back pressure.

60. In Fig. 35 (*a*) is shown an underwater exhaust containing three outlets, *a*, *b*, and *c*. The gases enter through the inlet *d* and are deflected toward the outlets and allowed to escape into the water. This device is shown installed in a boat, together with an expansion chamber in (*b*). The expansion chamber *a* is simply a



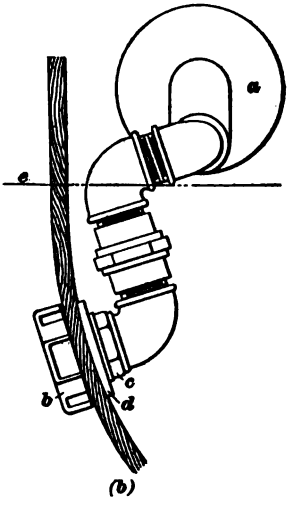


FIG. 35

cylinder into which the exhaust gases from the engine are led and allowed to expand before entering the exhaust header *b*. The header, or underwater exhaust, is held in place to the

outside of the side planking by the locknut *c*. Rubber packing is placed in the header against the outside of the boat and a wooden washer *d* is placed on the inside of the planking under the locknut, in order to prevent water from leaking into the boat around the threads under the nut. The water-line is shown at *e*.

The expansion chamber *a* and exhaust header *b* are connected up by means of elbows and a union, so as to form a sort of universal joint that will prevent the pipe from breaking in case of vibration of the boat. It is essential that some provision of this kind be made in piping connections on a boat, because the distance between any two separate parts so connected does not remain exactly the same, but varies on account of the vibration caused by the movement of the boat in the water.

REVERSING GEARS

61. In the handling of motor boats, it is often desirable to back the engine or turn the propeller opposite to that going ahead, even when there is only one set of gears for forward speed, and hence no speed-change device. In such cases, it is desirable to have a device by means of which the direction of motion of the propeller shaft may be reversed while the engine runs continually in the one direction. The reverse motion of the propeller is sometimes needed to check the speed to bring it to rest, or to run the boat astern.

There are several forms of such reversing mechanisms, but they are all similar in principle so far as the motion of the engine and propeller shaft is concerned, differing only in the method of making the connections for the reversal of motion. In some cases, spur gears and clutches are used; in others, spur gears and sliding feathers; and in still others, bevel gears.

62. In Fig. 36 is shown a reversing gear that depends on friction clutches for its operation. The propeller shaft is divided into two parts, the one connected to the propeller, carrying the gear *a*, and the other, connected to the engine, carrying the gear *b*. The gears *c* and *d* mesh with these gears.

The gear *b* is slightly smaller than gear *a*, and *c* meshes with *b*, and *d* with *a*. Another gear similar to *c*, but not shown, meshes with *d* and *b*, while one similar to *d* meshes with *a* and *c*.

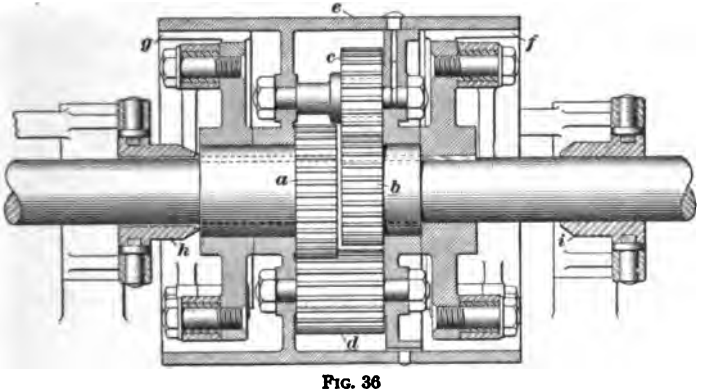


FIG. 36

The gears *c* and *d* run on pins that are held in place in the web of the drum *e*.

There are two friction clutches *f* and *g*, the latter serving to hold the drum *e* stationary when the movement of the propeller shaft is to be reversed. To reverse the motion of the propeller shaft while the engine is running, the spreader *h* is thrown inwards by the reverse lever, so that the clutch *g*, which is stationary, grips the drum *e* and holds it. The pins on which the gears *c* and *d* revolve are thus also held stationary, and the relative motions of the gears are as shown diagrammatically in Fig. 37. The crank-shaft transmits motion to the gear *b*, in the direction indicated by the arrow. The gear *c* in mesh with *b* turns in the opposite direction and transmits motion through a long gear *c'*, not shown in Fig. 36, to the gear *a* on the propeller shaft, which is thus made to move in a direction opposite to that of the gear *b* on the end of the driving shaft. The gear *b* is also in mesh with the gear *d'*, which turns gear *d* in the same direction as that in which the gear *c'* moves, and hence helps to turn gear *a* in a direction

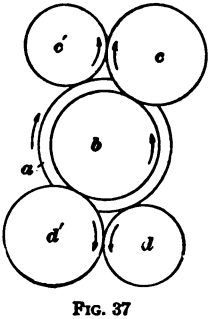


FIG. 37

opposite to that in which the driving gear *b* moves. The gears *d'* and *d* are duplicates of the gears *c* and *c'*, each pair transmitting a portion of the power when the lever is reversed. When the reverse spreader *h* is thrown out of engagement and the forward spreader *i* is thrown in, the same movement of the reverse lever serving to accomplish both operations, the clutch *f* grips the drum *e*, which is thereby caused to rotate with the driving shaft to which the clutch *f* is keyed, all the gears being locked together. The gears therefore have no relative motion,

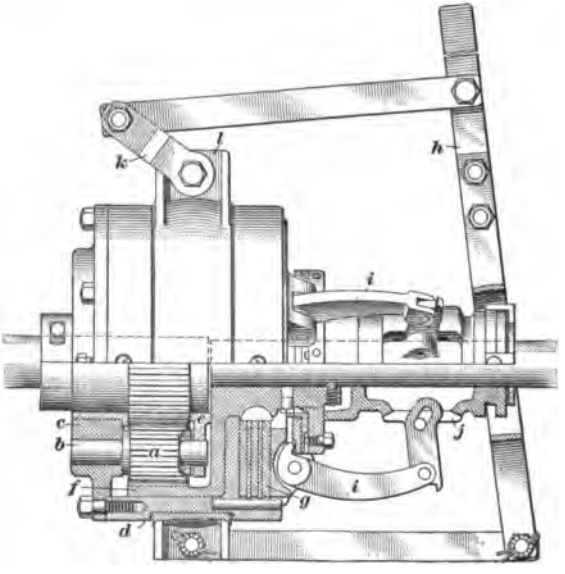


FIG. 38

and the whole mechanism, including the propeller shaft, rotates at the speed of the driving shaft.

63. In Fig. 38 is shown the Paragon reversing gear. The internal construction consists of a gear keyed to the crankshaft of the engine, surrounded by four or more pinion gears *a* running on studs *b* supported at one end by the cover *c*, which is bolted to the external case *d*, and at the other end by a bronze pinion support *e*. The pinion gears *a* in turn mesh with the propeller gear *f*, which is an internal gear.

The forward drive is obtained by a multiple-disk clutch, the surfaces of which are formed by the rear end of the propeller gear *f*, a partition or web in the case *d*, and thin plates *g*, one half of which are keyed to the case *d* and the other half to the propeller gear. When the lever *h* is thrown forwards, the fingers *i* are expanded by a togglejoint *j* so that the friction surfaces are clamped together, causing the propeller gear *f* and the case *d* to revolve as one piece. As the cover *c* is bolted to the case *d*

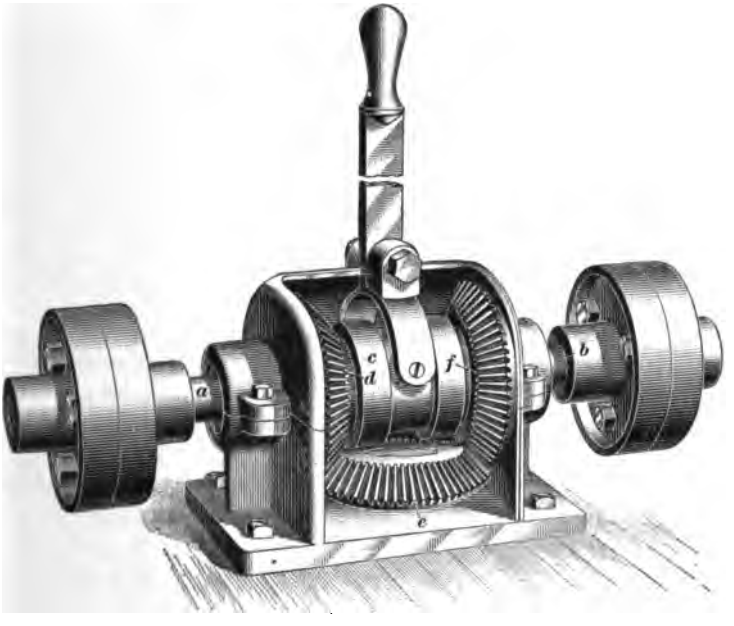


FIG. 39

and turns with it, the pinion gears *a* that are supported by the studs *b* in the cover and are in mesh with the propeller gear cannot revolve, and the whole device must turn as a solid coupling.

64. When the lever *h* is in the neutral position, which is its vertical position, the friction surfaces are released, the pinion gears *a* run idly, and only the case *d* revolves, so that no motion is transmitted to the propeller.

The reverse motion is obtained by throwing the lever *h* backwards, or to the rear. The inclined lever *k* rides upon a double cam, which draws the brake band *l* together and clamps the outside case *d*, preventing it from revolving. The cover *c* that is bolted to *d* is also held stationary and the pinions *a* are caused to revolve in a direction opposite that in which the engine runs. The gears *a* drive the propeller gear in the opposite direction from that in which the engine is running, and thus the reverse motion is obtained.

65. A somewhat different type of reversing gear is shown in Fig. 39. The driving shaft *a* is connected directly to the propeller shaft *b* by the clutch coupling *c* in the position it now occupies. In this position the gears *d*, *e*, and *f* do not transmit power, but the gear *f* turns idly on the propeller shaft. By throwing the clutch coupling to the other side, however, the shafts are disengaged and the clutch holds the gear *f* rigidly to the shaft *b*, and the direction of rotation is reversed.

SCREW PROPELLERS

66. The **screw propeller** is a very important part of the power equipment of a launch or motor boat. The rotary motion imparted to the crank-shaft by the gas engine inside the boat is given to the propeller outside the boat, and by its action on the water the boat is propelled forwards or backwards. Motor boats are seldom run backwards for any great distance, the backward motion being principally used when getting away from a wharf or dock, when stopping quickly, or when turning in a small space. The boat always moves more rapidly forwards than backwards, with the same expenditure of power.

Figs. 40 and 41 show two forms of propellers. Fig. 40 has a very wide blade near the end, while Fig. 41 has the greatest width at a point about one-third the distance from the end of the blade. Propellers are also made with two and with four blades; when made with two blades they are opposite, or 180° apart. The blades on a four-bladed propeller are equally spaced around the hub.

67. As the propeller turns in the water, its motion is resisted by the water, and this resistance increases with the speed of the propeller; besides, when a propeller turns very rapidly, it churns the water without increasing the speed of the boat. The speed limit of propellers seems to be reached in practice at about 800 revolutions per minute; it is probable that, at speeds in excess of 800 revolutions per minute, even in very light boats, any increase in power at the engine is more than counterbalanced and neutralized by propeller losses. In heavy, or working, boats, the loss of efficiency at high speed is very much greater than in light boats. In heavy head winds, working boats that make but little progress with the engine running at 350 revolutions per minute will do considerably better at 20 per cent. less speed.

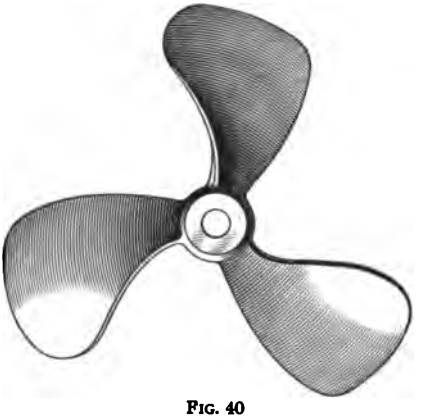


FIG. 40

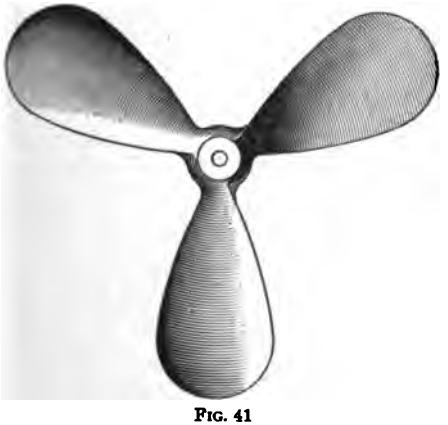


FIG. 41

68. The **pitch** of the propeller is the axial, or longitudinal, distance through which the propeller would force the boat, during one revolution, if there were no resistance to the boat's forward motion, and if the propeller had no lost motion due to its revolving in a non-solid substance. The amount these losses reduce the forward motion of a boat is called the **slip**. The pitch of a propeller is measured in the same way that the pitch of a screw is measured.

A propeller with the same pitch for all points of the blade is said to have *uniform*, or *true*, *pitch*. A propeller blade has *increasing*, or *expanding*, *pitch* when the pitch increases from the axis to the tip of the blades, and *decreasing pitch* when the pitch at the axis is greatest and it decreases toward the tip of the blade. *Compound pitch* is any combination of pitches. The propeller might have true pitch at some parts, and increasing or decreasing pitch or both at other parts.

69. The *driving surface* of a propeller is usually the flat side of the blade that pushes the water astern, while the *crowning surface*, or *front*, is the part that draws the water toward the propeller.

The *cutting edge* is the part of the propeller blade that first enters the water when driving the boat ahead.

The *projected area* of the blades is the surface that forces the water back, and is measured at right angles to the direction of motion of the water, while the *developed area* is the entire driving surface of the blades, usually called the *blade surface*.

The accepted form of blade surface to give the best results is what is known as a *warped surface*. In some one direction on such a surface, straight lines can be drawn, but to the eye, and by the application of a straightedge in any other direction, it has a slightly dished or concave surface.

70. In some cases it is found expedient to use **reversing** or **feathering blade propellers.** The blades may be feathered, or the angle at which the driving surface strikes the water may be so changed that the water is driven ahead instead of astern, without reversing the direction of rotation of the propeller shaft. Midway between the ahead and the astern position is a neutral zone in which an equal power in both directions is exerted, with no effect on the boat in either direction. There is usually but one position of the blades that approximates true pitch, and on this account there is a considerable amount of power lost in their use, unless they are very carefully designed and specially built.

A sleeve sliding on the shaft and connected to the blades themselves, often within an enlarged hub, or attached to it and

operated by means of a lever or hand wheel inside the hull, is sometimes used to control the position of the blades. Such an arrangement is shown in Fig. 42 (*a*). The propeller blades are shown at *a*, the outside stuffingbox at *b*, the stern bearing at *c*, the sliding sleeve at *d*, the inside stuffingbox at *e*, and the reversing lever at *f*. One of the blades separate from the device

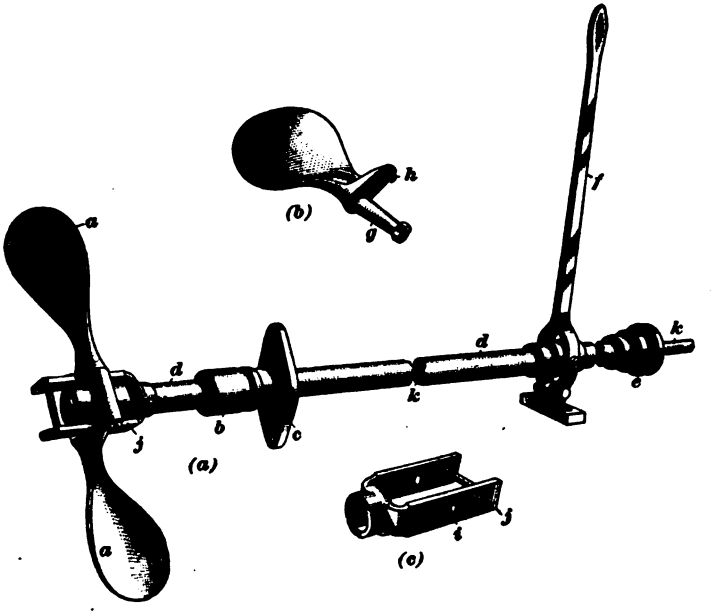


FIG. 42

is shown in (*b*), with the pivot *g* that fits into the hub and about which the blade turns. The pin *h* of this blade fits into the slot *i* in the fork *j*, views (*a*) and (*c*). The fork is attached to the sleeve *d*, and as the sleeve is moved forwards or backwards the fork moves the pins so as to cause both blades to turn about their pivots. The propeller shaft is shown at *k*. The sliding sleeve revolves with the shaft, but is free to be moved along the shaft by the lever *f*.

MARINE GASOLINE ENGINES
(PART 2)

MARINE-ENGINE EQUIPMENT

CARBURETERS

DEFINITIONS

1. When a combustible vapor and air are mixed in proper proportions and ignited, the combination of the gas with the oxygen of the air is so rapid as to produce an **explosion,** which may be defined as an extremely rapid combustion accompanied by the formation of gases and increased pressure. The sudden rise of pressure produced is made available for driving internal-combustion engines, of which the marine engine is one type.

2. Two or more elementary substances may be mixed together and yet not combine to form a new substance; they are then said to form a **mixture.** The mixture has the properties of the elements composing it. The most familiar mixture is ordinary air, which is composed of 23 parts, by weight, of oxygen and 77 parts, by weight, of nitrogen. The two gases do not combine chemically; they are simply mixed.

A mixture of two or more substances whose chemical combination will cause an explosion is called an *explosive mixture.* An explosive mixture of gasoline vapor and air is composed of the vapor of 1 part of liquid gasoline to from 8,000 to 10,000

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parts of air, by volume. The volume of the vapor will vary, but an average proportion will be 2.15 parts of gasoline vapor to 100 parts of air.

The enriching of air, as by adding to it the vapor of gasoline, naphtha, kerosene, alcohol, etc., is called **carburation** of the air; the device used for carbureting the air is called a **carbureter.** The mixture formed is variously called the *combustible mixture*, the *gas*, or simply the *mixture*.

3. The operation of setting fire to the gaseous mixture in the engine cylinder by means of a device called an **igniter** or a **spark plug** is known as **ignition.** The moment that ignition begins is called the *time of ignition*. When all the charge, or mixture of gas and air taken into the cylinder at one time, is ignited, it is said to be wholly inflamed. The time elapsing between the time of ignition and the moment when the gas is wholly inflamed is known as the *duration of inflammation* or duration of the explosion. The velocity with which the flame is generated in the charge is called the *rate of flame propagation.*

COMBUSTION AND FUELS

4. Liquid Fuels.—The internal-combustion engine used on motor boats burns the fuel inside the engine cylinder, as the name indicates. The fuel used is gasoline, naphtha, or kerosene, and in rare cases, alcohol. Naphtha is practically the same as gasoline, so that the same process of vaporization and mixing with air applies to both. Kerosene is heavier, harder to vaporize, and requires a slightly different process of vaporization. All of these fuels are obtained in the liquid form and must be vaporized for use in the engine. The burning, or combustion, of the fuel liberates *heat*, which is a form of energy. The function of the engine is to convert some of this heat energy into mechanical energy, which can be utilized to perform the work of propelling the boat.

5. Combustion.—Combustion is a very rapid chemical combination. The atoms of some of the elements have so great an affinity, or attraction, for those of other elements

that when they combine, they rush together with such rapidity and force that heat and light are produced. Oxygen, for example, has a great attraction for nearly all the other elements, but especially for carbon and hydrogen, with which whenever it comes into contact at a sufficiently high temperature, it combines with great rapidity.

The combustion in a marine-engine cylinder is of this nature. The temperature of a small portion of the mixture of gas and air is raised by an electric spark, and then the fuel charge begins to combine with oxygen taken from the air. The combination is so rapid and violent that a great quantity of heat is given out, and this heat suddenly raises the temperature of the mixture. **Combustion,** therefore, is the rapid chemical combination of two or more substances, resulting in the production of heat.

6. Products of Combustion.—The gases produced by, or remaining after, combustion in a marine-engine cylinder are known as the **products of combustion,** though they are frequently called the **exhaust gases,** or simply the **exhaust.**

All the fuel oils and gases are chemical compounds of hydrogen and carbon, and are called *hydrocarbons*. When burned in oxygen, they split up and the hydrogen and carbon unite separately with the oxygen in the air, producing water vapor and carbon dioxide, respectively. When, as is ordinarily the case, the oxygen is obtained from the air, the nitrogen of the air passes into the engine cylinder along with the oxygen; it then takes no part in the combustion and passes off through the exhaust with the carbon dioxide.

7. Ordinarily there is some moisture in both the air and the gas, or vapor; therefore, the gases produced by the combustion of any of the combustible mixtures contain some steam because of the chemical combination of the oxygen of the air and the combustible elements of the fuel. If the gaseous products are cooled to a temperature as low as that of the atmosphere, the steam will condense into the form of water.

The heat of burning a gaseous combustible mixture increases the volume of the gas if the pressure is kept constant, as when

the mixture is burned in the open air; but if the mixture is confined in a closed space, so that the gases cannot expand and increase their volume, the burning increases the pressure against the walls of the enclosing vessel. As the gases cool after burning at constant pressure, the volume contracts. In the case of constant volume, the pressure falls as the temperature decreases.

8. **Gasoline.**—Internal-combustion engines equipped with carbureters use fuels composed of hydrogen and carbon. Gasoline is the fuel in most general use, and its behavior is typical of all fuels used in engines of this class. It is produced in the early stages of the distillation of petroleum and is a mixture of various substances of different evaporative rates, depending on the extent to which the distillation is carried. At one time, gasoline was much cheaper than kerosene, and the tendency was to produce as small a proportion of gasoline as possible from the crude oil; in other words, to market gasoline of high evaporative rate. The development of this type of engine for motor-boat and automobile use, however, has created a demand for gasoline that has raised its price considerably, and the refiners now produce more gasoline from the same crude oils. As a result, the commercial gasoline of today has a much lower evaporative rate than formerly, and the tendency is to produce a still heavier gasoline.

9. Gasoline is particularly adapted for use in modern marine engines on account of its high evaporative rate at moderate temperatures, evaporation being an essential to thorough mingling and complete combustion of the charge in the limited time available. Gasoline has not, however, a definite chemical composition, but is a mixture of various substances having different evaporative rates. At low temperatures, certain of these substances are not readily vaporized so as to give their maximum effect in the engine. In fact, vaporization is sluggish at very moderate temperatures, owing to the cooling effect of the evaporative process on the inspired charge and on the carbureter and intake pipes, as is shown in cold weather, when a considerable excess of fuel makes starting

a cold engine easier. This excess is required because only the lighter portions of the fuel are, at that temperature, evaporated and available for ignition, the heavier portions being inert.

10. Testing of Gasoline.—Gasoline varies considerably in quality; the lighter it is in weight, the more volatile and better it is for use in gas engines. It should also be free from water. A poor quality of gasoline makes it difficult to start an engine, especially when the gasoline is cool. The specific gravity, or relative weight, of gasoline is determined by means of an instrument called a **Baumé hydrometer,** or simply a **hydrometer.** An ordinary hydrometer for testing gasoline, shown in Fig. 1, consists of a glass tube, near the bottom of which are two bulbs. The lower and smaller bulb *a* is filled with sufficient mercury for the instrument to remain vertical when placed in the liquid in a vessel *b*. The upper bulb *c* is filled with air, and its volume is such that the whole instrument is lighter than an equal volume of water. The stem *d* of the hydrometer is graduated in degrees in much the same manner as a thermometer; the graduations on this particular instrument run from 60° to 80°. Sometimes the stem is made longer and there are a greater number of graduations, a scale running from 50° to 90° being quite common. When placed in gasoline or some similar liquid, the instrument sinks so that both bulbs, as well as a portion of the stem, are beneath the surface. The lighter the liquid, the farther the hydrometer sinks into it; hence, the reading on the scale at the surface of the liquid gives its relative weight or specific gravity in terms of *degrees Baumé.*

11. The large bulb *c* of the hydrometer shown in Fig. 1 has a scale for making temperature corrections in the specific gravity of a liquid. The readings on the stem give the correct number of degrees Baumé when the liquid is at 60° F., but when the temperature varies from this, the relative weight of the liquid also varies from that marked on the stem. On the large bulb *c* is a regular Fahrenheit thermometer scale, with a scale of corrections to be made for the various temperatures directly opposite it. At 60° F., the correction is 0, hence the reading on the stem at this temperature is correct. When the temperature

is above 60° F., the correction is to be subtracted from the reading at the surface of the liquid on the stem; when the temperature is below 60°, the correction should be added to the reading on the stem. For example, in Fig. 1 the reading on the stem is 67° and the correction is about 3. As the tempertaure is above 60° F., 3 is subtracted from 67; therefore, the correct specific gravity is 67 −3=64°.

FIG. 1

Originally, gasoline had a specific gravity of about 76°, but the increased demand for this fuel, due to the great activity in the motor-boat and automobile industries has brought about a great change. The gasoline now marketed has a specific gravity of about 58° or 60° and its vaporizing qualities have been reduced in proportion.

12. Kerosene.—On account of the decreasing quality and the increasing cost of gasoline, other fuels are being brought out and carbureters are being designed especially for use with kerosene, alcohol, etc. Kerosene is being used along with gasoline in a number of marine engines. The gasoline, being more easily vaporized, is used to start the engine, after which the kerosene is turned on and used for ordinary running.

So far as heating value per pound is concerned, there is not much choice between kerosene and gasoline, each developing about the same amount of heat per pound. Kerosene, however, is about 10 per cent. heavier, so that a gallon of kerosene has greater fuel value than a gallon of gasoline. If kerosene were as easily evaporated as gasoline it would doubtless supplant that fuel to a very much larger extent.

13. Mixtures of Gasoline and Air.—A given volume of air, as 1 cubic inch, can absorb only a certain amount of gasoline vapor, just as water can dissolve no more than a certain amount of salt. A mixture containing less than this amount of vapor is neither a saturated nor a perfectly proportioned mixture, and is said to be lean; a mixture containing more than this amount of vapor is not a perfectly proportioned mixture and is said to

be rich. The proper mixture of gasoline and air for explosive purposes in a gasoline-engine cylinder burns, at atmospheric pressure, with a blue flame, and leaves little or no sooty, or carbon, deposit on the walls of the vessel. Lean mixtures behave in the same way, except that when they burn in a confined space, the pressure produced is less than that produced by a perfect mixture, because the volume of combustible mixture is less. The surplus air does not burn; it is heated, however, and, of course, expands some. A more intense explosion will be produced by a proper amount of gasoline vapor and air if the two are first thoroughly mixed together.

14. As gasoline vapor is heavier than air, it tends to sink to the bottom of a vessel containing it, and unless agitated it mixes but slowly with the air above it. For this reason, a room in which gasoline vapor is present cannot be well ventilated by openings near the ceiling; but openings through the floor or under a door will allow the vapor to pass out. The room can also be ventilated by a flue whose bottom opening is at the floor, provided there is a current of air passing upwards through the flue. If the flue has no draft, as may be the case in damp weather, some artificial means, such as a fan or a coil of steam pipe, must be used to induce it.

PRINCIPLES OF CARBURETERS

15. A **carbureter,** or **vaporizer,** is an appliance for vaporizing liquid hydrocarbons by passing air over the surface or through the mass of the liquid, or by atomizing the liquid and mixing it with air. The air thus becomes saturated with the vapors of the hydrocarbon. This mixture invariably contains too large a proportion of vapor for an explosive mixture; therefore, before the mixture can be exploded in the engine cylinder, it requires the further addition of air.

16. Spray Carbureters.—The type of carbureter that vaporizes, or atomizes, the hydrocarbon and injects it into a current of air is known as the **spray carbureter.** This form of carbureter is used exclusively on marine gasoline engines,

the other forms having been abandoned. In the spray carbureter, the gasoline is given to the air in the form of a jet, or spray, that is drawn from the supply by the air-current. When the air is sufficiently warm, this spray is evaporated and a fairly constant mixture of air and gasoline vapor is thus obtained.

17. The spray carbureter has a nozzle with one or more small, almost minute, openings, or orifices. For convenience of discussion, it will be assumed at first that the nozzle has only one orifice. The air passing to the engine draws the gasoline out of the orifice of the nozzle. When the gasoline thus drawn out forms a spray, it almost instantly vaporizes and mixes with the air, so as to form, under favorable conditions, a combustible mixture.

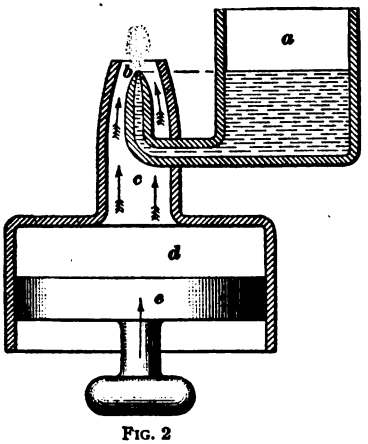


FIG. 2

In some carbureters, the spray orifice is slightly above the constantly maintained level of the body of gasoline to which it connects; in others, the orifice is below the level of the gasoline, and it is automatically stopped by a valve so that the liquid cannot flow from it when not required for enriching the air.

18. Some of the elements of a spray carbureter are shown in Fig. 2, which is a diagrammatic illustration showing how the gasoline is drawn into the air in a spray and vaporized. At *a* is shown a reservoir, containing the liquid fuel, and at *b*, the nozzle, which has an orifice that opens vertically upwards and is connected to the gasoline in the reservoir *a* by the passage shown. This passage is considerably larger in sectional area than the orifice. The nozzle is surrounded by a vertical tube *c*, which is somewhat contracted at the top, so as to make the opening leading to the atmosphere smaller than that through the body of the tube. The tube *c* is connected at the bottom with a cylinder *d*, into which fits a freely moving piston *e*.

In order to illustrate the principle of operation, it will be assumed that the top of the nozzle *b* is of the same height, or on the same level, as the surface of the gasoline in *a*. If the piston *e* is moved upwards, so as to force air out through the tube *c* past the nozzle *d*, as indicated by the feathered arrows, a spray of gasoline will be drawn out of the nozzle. In this case, the pressure of the air passing out by the nozzle is greater than that of the atmosphere acting on the surface of the liquid at *a*. Under this condition, no gasoline would be drawn from the nozzle if it were not for the effect of the velocity of the air-current. The moving air-current has a tendency to form a partial vacuum immediately around the nozzle opening. It is by this action of the moving air that the gasoline is drawn out.

19. In the practical carbureter there is no piston like that shown at *e*, Fig. 2, the air being drawn past the spray nozzle by the suction of the engine piston in the cylinder. By the same suction the mixture of air and gasoline vapor is drawn into the cylinder. The tube *c* is not always contracted but in several makes of carbureters it remains of the same cross-sectional area throughout. However, the practice of narrowing the tube in actual carbureters is quite common. This variation of diameter from the larger to the smaller size is gradual.

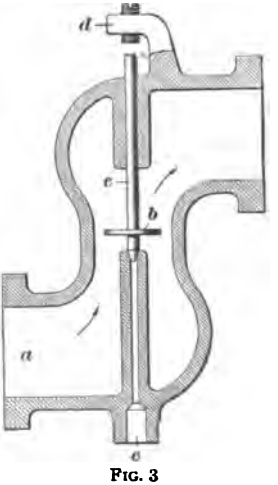


FIG. 3

MIXING VALVES

20. A simple form of vaporizer, known as a **mixing valve**, is often fitted to marine engines. It consists of a needle valve opening into an air passage, or pipe, through which air is drawn into the cylinder of the engine.

A very simple mixing valve is shown in cross-section in Fig. 3. The air enters at *a*, and, as it passes upwards in the constricted passage, it impinges sharply on the small flange *b* of the needle valve *c*, thereby lifting the valve, the amount of lift depending on the

velocity of the air-current. In this way, the flow of the gasoline is regulated roughly according to the velocity of the air. A stop *d* above the needle valve prevents it from lifting so high that it will not have time to close by its own weight at the end of the stroke. The connection to the gasoline supply is

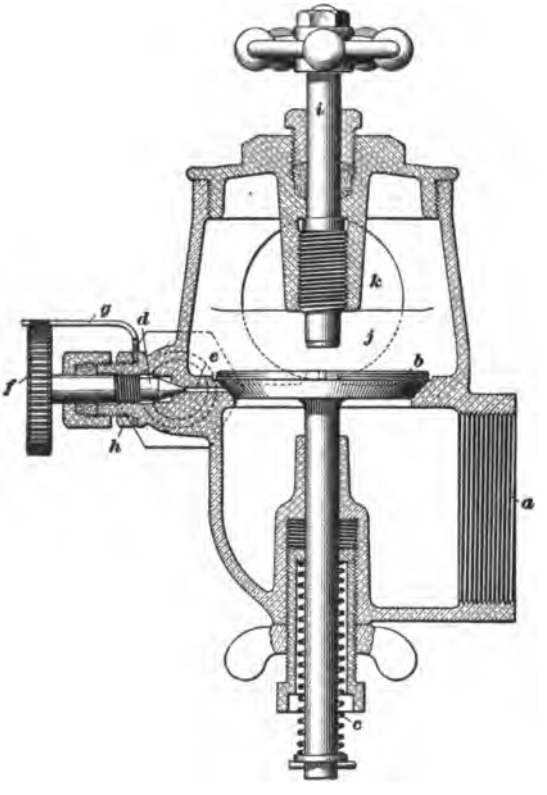


FIG. 4

made at *e*, and the gasoline rises to the needle valve by the pressure due to the height of the gasoline tank.

21. The vaporizer shown in Fig. 4 is used to a considerable extent in motor boats. Its operation depends on the vacuum produced by the suction of the engine. The pressure of the air that enters at *a* lifts the valve *b* against the

pressure of the spring *c*, when the engine is taking in a new charge. As the gasoline enters around the needle valve *d* it is sprayed from the passage *e* when the valve *b* is lifted off its seat. The graduated hand wheel *f* of the needle valve indicates the opening, the pointer *g* being locked in any position by the locknut *h*. The stop *i* can be adjusted so as to give the desired amount of opening to the valve *b*. A baffle wall *j* deflects the mixture upwards and causes it to mix more thoroughly without reducing the area of the passage *k* through which it passes to the engine. The baffle wall also serves to prevent any liquid gasoline from flowing to the engine.

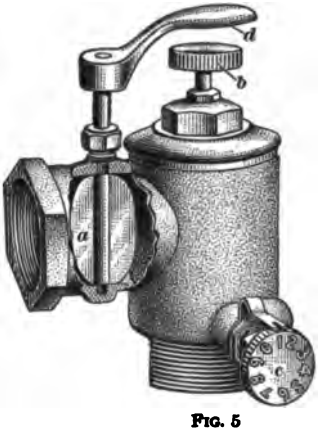


FIG. 5

22. A vaporizer operating on the same principle as that illustrated in Fig. 4 is shown in Fig. 5. This mixing valve is fitted with a throttle valve *a*, by means of which the amount of mixture flowing into the engine, and therefore the engine speed and power, may be controlled by hand. The lift of the valve inside of the vaporizer is regulated by the adjusting screw *b*, as in Fig. 4, and the gasoline needle valve is regulated by the screw *c*. The screw *c* is graduated so that the distance through which it is turned may be noted, and thus the size of the opening in the needle valve obtained. The hand lever *d* is for the purpose of operating the throttle valve *a*.

23. Vaporizers, or mixing valves, like the ones shown in Figs. 4 and 5, are much less common now than in the past. They are very wasteful of gasoline, and require frequent adjustment to make them supply the proper mixture. The gasoline flows more rapidly to the needle valve when the tank is full than when it is nearly empty, on account of the difference in pressure due to the height of the surface above the valve. Also, the proportion of air to gasoline is not entirely constant when

the engine speed changes, or when the engine is throttled. The tendency is for the mixture to be too rich at high-engine speeds, as the flow of gasoline is not only due to the pressure from the elevation of the tank, but also to the partial vacuum existing in the mixing chamber and to the velocity of the air. Even if no vacuum existed in the mixing chamber and if the gasoline had no pressure at the needle valve, the gasoline would be drawn into the air by the velocity of the latter. As a result, four factors affect the proportions of the mixture; the head of the gasoline in the tank, the lift of the needle valve, the vacuum in the mixing chamber, and the velocity of the air. What is really desired, is that only the last named of these four factors should be operative; or, in other words, that the velocity of the gasoline jet should be in direct proportion to the velocity of the air. This is not attained in the type of carbureter just described.

TYPICAL CARBURETERS

24. Operation of Float-Feed Carbureters.—The almost universally adopted method of maintaining a constant, or nearly constant, level of gasoline in the reservoir of the carbureter, is by means of a float to which is attached a valve that cuts off the inflow of gasoline from the supply tank when the liquid rises to a predetermined level; this device is called a *float feed*. The float is, of course, placed in the gasoline contained in the carbureter reservoir and is adjusted to maintain a gasoline level slightly lower than the top of the nozzle. This is done to secure a margin of safety to allow for inaccurate operation of the float and valve, so that there will not be excessive flow of gasoline from the nozzle in case the float allows the liquid to rise slightly above its normal level; also, to prevent dripping when the engine is idle, and overflow due to the tipping of the carbureter when the boat is pitching or not on an even keel.

The average height of the spray nozzle above the normal gasoline level when the carbureter is level, as found in general practice, is about $\frac{1}{16}$ inch. It is sometimes, although not often, less than this amount, and is seldom more than $\frac{1}{8}$ inch, although in a few cases it is as much as $\frac{3}{16}$ inch or more.

25. A simple form of **float-feed carbureter** is shown in Fig. 6. Gasoline from the supply tank enters the bottom of the carbureter at *a* and flows up past the valve *b* into the float chamber *c*, which is not perfectly air-tight above the float. Part of the gasoline flows into the passage leading to the spray nozzle *d*. As the gasoline rises in the float chamber it lifts the float *e* and also the valve *b* attached to the float. When the gasoline reaches a level slightly below the top of the spray nozzle *d*, the valve *b* closes the inlet passage to the float chamber and thus stops the inflow of gasoline. The upper end of the

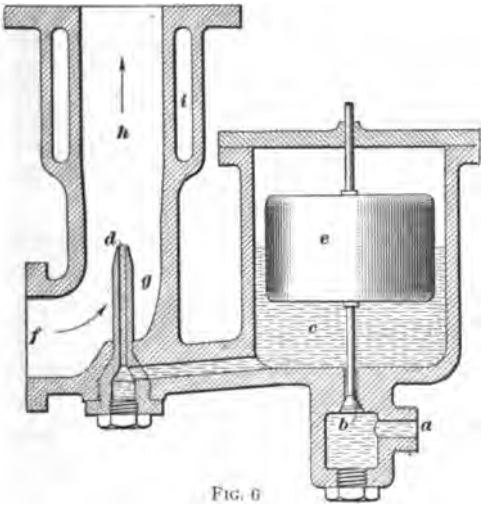


FIG. 6

chamber *h* is connected to the engine intake. The suction of the engine draws air through the opening *f* of the air passage *g*, past the nozzle *d*, into the mixing chamber *h*, and out at the top thereof, as indicated by the arrows. On account of the velocity of the air passing the nozzle *d*, and the pressure at *d*, which is lower than that upon the surface of the gasoline in the float chamber *c*, gasoline is drawn out from the spray nozzle; the float *e* therefore descends slightly, because of the lowering of the gasoline in the float chamber, and the float valve *b* is slightly opened, so as to allow more gasoline to enter and thus maintain a nearly constant level in the float chamber.

The vaporization of the gasoline requires heat, part of which is drawn from the walls of the air passage or mixing chamber *h*. This withdrawal of heat leaves the metal around the air passage cold, at times even below the freezing point of water. The coldness retards the rapidity of vaporization, and in some cases interferes with the satisfactory operation of the carbureter. To prevent this, a jacket space *i* is provided around the mixing chamber and water from the cylinder water-jackets may be circulated through this jacket space to keep the carbureter warm.

26. Priming the Carbureter.—When cranking an engine by hand to start it, the suction and velocity of air through the carbureter are generally not great enough to draw sufficient gasoline from the spray nozzle of a float-feed carbureter to make a mixture sufficiently rich to be ignited in the engine. This is principally because the normal level of the gasoline is below the top of the spray orifice, as stated. Some hand-operated device, by means of which a small quantity of gasoline can be caused to flow into the air passage, is therefore generally incorporated in carbureters of the float-feed type. This gasoline is then readily vaporized, and the vapor is mixed with the air drawn into the carbureter, so that the engine receives a combustible mixture while being rotated at slow speed by hand. The flowing of gasoline into the air passage of a carbureter by hand-operated means, as just described, is called *priming the carbureter*.

The carbureter, Fig. 6, can be primed by pressing down the stem extending from the float through the cover of the float chamber. When the valve and float are thus depressed, gasoline will flow in from the supply tank, past the float valve, and out of the spray nozzle. Other methods of priming the carbureter are described in connection with the carbureters on which they are used.

27. Automatic Carbureters.—The carbureter shown in Fig. 6 may give a mixture richer in gasoline when the air passes through it rapidly than when it passes at a slower rate. In order to produce a mixture as nearly constant in its proportions

of air and gasoline vapor, as possible, an automatic air valve is generally placed on the carbureter to control the inflow of air into the carbureter, as is shown in Fig. 7. As before, the gasoline from the supply tank flows in at *a* and passes into the float chamber until the float *c* rises so as to close the float valve *d* when the level of the gasoline nearly reaches the top of the spray nozzle *e*. A comparatively small air intake is connected to the mixing chamber *g* by an open passage. An auxiliary air intake is closed by the compensating automatic air valve *f* when the suction produced by the piston, and hence the demand

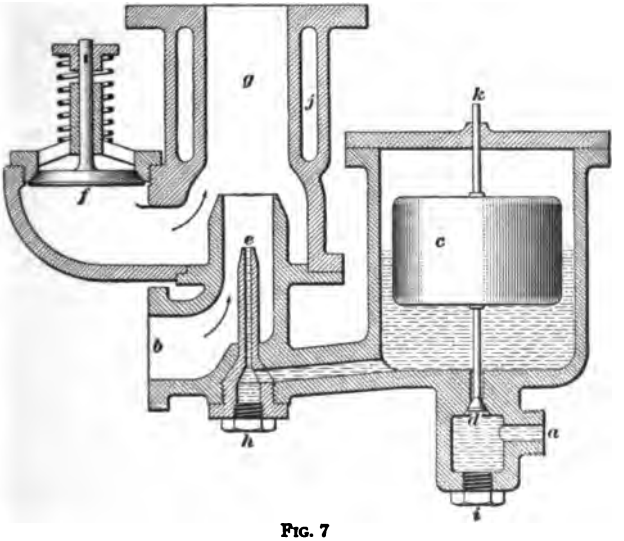
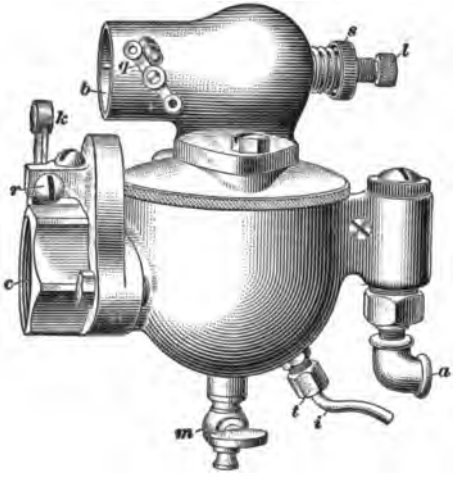


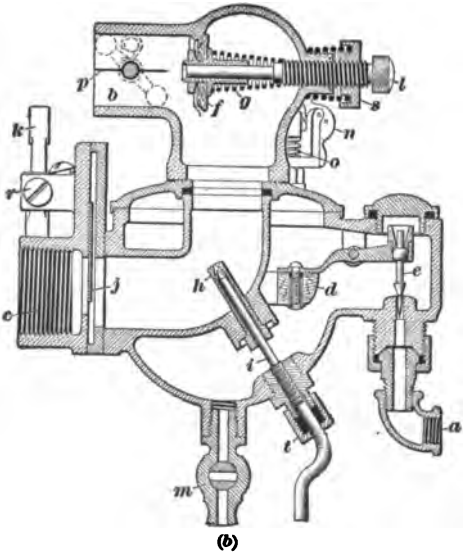
FIG. 7

for mixture, is light; but when the engine is drawing mixture rapidly, the suction is sufficient to open the spring-closed compensating air valve *f* and automatically admit more air. This admission of air through the compensating valve restricts both the suction and velocity effects at the spray nozzle *e*, and also supplies pure air to dilute the overrich mixture formed in the small air passage leading from the open intake *b* past the spray nozzle into the mixing chamber.

28. Two plugs *h* and *i* are provided for cleaning the carbureter of any foreign matter, as dirt, and water that may be



(*a*)



(*b*)

FIG. 8

carried in with the gasoline. As almost all such matter is heavier than gasoline and tends to settle to the bottom, it is only necessary to unscrew these plugs and cause a little gasoline to flow through in order to clean the carbureter. The annular jacket *j* is connected, by pipes not shown, with the water-jacket of the engine; in this way, the heat required by the gasoline in the process of evaporation is supplied, thus preventing condensation and freezing of the moisture in the air.

To start the engine, the stem *k* is depressed, thus opening the valve *d* and permitting the gasoline to escape freely from the spray nozzle. Sufficient gasoline is thus allowed to gather in the intake pipe to produce, simply by evaporation, the mixture necessary for starting.

29. Schebler Carbureter.—In Fig. 8 are shown two views of the model D, Schebler carbureter, (*a*) being an external view and (*b*) a cross-section through the middle. This carbureter differs in a number of ways from that illustrated in Fig. 6 and is very largely used. Identical parts are lettered the same in each view as far as possible. The gasoline enters at *a*; if the float *d* is low enough, the valve *e* is held open so that the gasoline flows into the float chamber until the float rises and the gasoline is shut off by the lowering of the valve *e*. In the passage *b* is an automatic air-inlet valve *f* that is closed by the spring *g*. This valve does not entirely close the air passage when it rests on its seat, for at the bottom is left an opening through which sufficient air for the engine at its lowest speed can enter. As the suction increases, this valve opens against the spring *g*, thereby admitting a larger quantity of air. All air that enters passes downwards, instead of upwards, as in most carbureters, past the spray nozzle *h* and strikes against the end of the nozzle. When the velocity of this down-flowing air is sufficient, as at high engine speed, it has a tendency to check the flow of gasoline from the spray nozzle. The nozzle *h* projects into the middle of the air passage, and the cork float is made in the shape of a horseshoe in order to fit the peculiar shape of the float chamber. As the opening of the spray nozzle is exactly in the center of the float chamber, the carbureter is not much

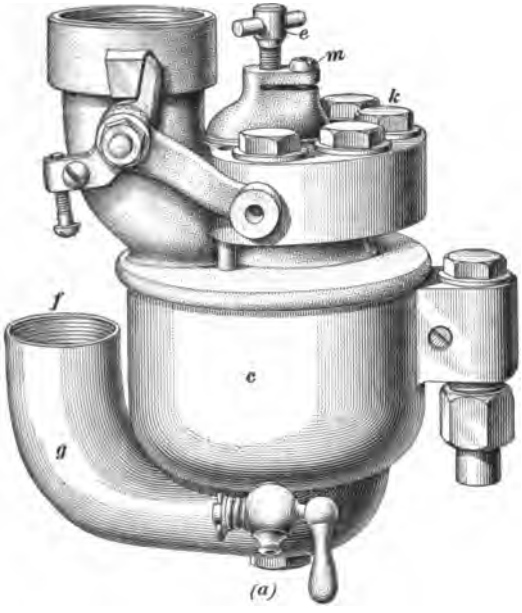
affected when tilted. By means of the pointed stem, or needle valve *i*, the opening in the spray nozzle can be adjusted. The throttle valve *j* is opened and closed by means of the lever *k*. Adjustment of the automatic air valve *f* is obtained by modifying the tension of the spring *g* by screwing up or unscrewing the shouldered stem *l*, which extends through the valve *f* to guide it, but is not attached to it. A drain cock *m* at the bottom of the float chamber provides for emptying or drawing off water that may have entered it.

30. When starting the engine, the float *d* is depressed by means of the lever *n*, which depresses the pin, or *priming device*, *o*. This allows the level of the gasoline to rise above the nozzle *h*, so that enough gasoline can enter the air passage to start the engine.

The carbureter is connected to the intake manifold of the engine at *c*. A valve *p* in the auxiliary air passage *b* may be closed by the lever *q* to make the starting of the engine easier in cold weather. When closed, or partly closed, it restricts the entrance of air and causes greater velocity of the air from the fixed opening past the spray nozzle, thereby producing a richer mixture.

31. Adjustment of Schebler Carbureter.—The first step in the adjustment of the Schebler carbureter is to turn the screw *l*, Fig. 8, until the valve *f* seats lightly, but firmly. The spray nozzle *h* should then be closed by turning the stem *i* right-handed, after which it should be opened by giving it about three-quarters of a turn left-handed. In order to adjust for low speed, the spark should be retarded, the throttle opened about one-fourth, and the gasoline turned on. The needle valve *i* should then be adjusted until the engine runs smoothly without missing. The throttle should be set by means of the screw *r* to prevent it closing completely.

When adjusting the carbureter for high speed, the throttle should first be opened wide and the spark advanced about one-quarter. If the engine does not run smoothly, but back-fires, the tension of the air-valve spring *g* is too weak. In such cases, the adjusting screw *l* should be given two complete turns right-



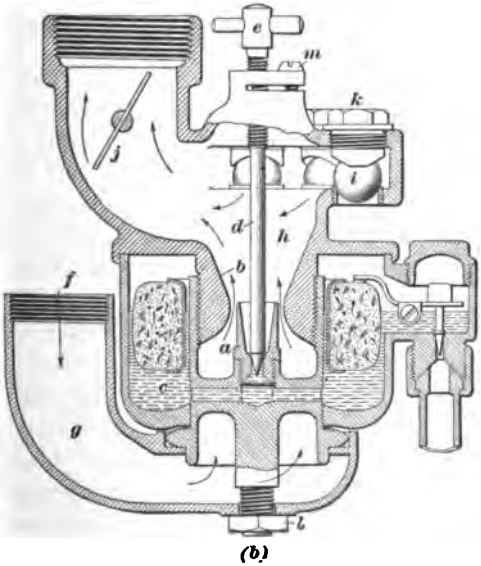


FIG. 9

handed. If this does not eliminate the irregularity, the needle valve *i* should be given about one-tenth of a turn left-handed, thus giving the mixture a trifle more gasoline. The engine should then run smoothly and regularly. After the adjustments have been made the nuts *s* and *t* should be tightened.

32. Construction and Action of Kingston Carbureter.—The construction of the Kingston carbureter is shown in Fig. 9 (*a*) and (*b*). The nozzle *a* is in the center of the tube *b* and is surrounded by the float chamber *c*. The flow of gasoline is regulated by a needle *d* that extends beyond the top of the carbureter and is fitted with a winged head *e*. The main air supply enters at *f*, flows through the horn *g*, and rises around the nozzle *a*, passing thence into the mixing chamber *h*. The auxiliary air enters the mixing chamber by lifting one or more of the balls *i* from their seats. These balls are of bronze and are held in a cage formed by the cap *k*; they all have the same diameter and hence the same weight. The mixture then passes the throttle valve *j* and enters the inlet manifold. The horn *g* may be swiveled on the stem *l*, so as to take air from any direction. The screw *m* locks the needle *d* in position after the latter has been adjusted.

33. Adjustment of Kingston Carbureter.—The Kingston carbureter, Fig. 9, has but one adjustment, namely, that of the spray nozzle. When the needle *d* has once been set correctly at low speed, the correct explosive mixture at other speeds will be produced by the automatic action of the balls *i*. To adjust this carbureter, the head *e* of the needle *d* is turned to the right until it will go no farther. The gasoline nozzle *a* will then be completely closed. The screw *m* should be loosened, so that the needle *d* may turn easily. The needle should now be given one complete turn to the left, and the engine should be started. With the spark retarded, the throttle slightly open, and with the engine running, the needle *d* should be slowly turned to the right until the engine begins to back-fire; then it should be turned slowly to the left until the engine runs at its maximum speed for that throttle opening, after which it should be locked in this position by tightening the screw *m*.

34. Kerosene Carbureters.—The fact that kerosene will not vaporize readily at the ordinary temperature of the air entails the employment of some special means to vaporize it sufficiently for use as fuel in an internal-combustion engine. The means usually taken to vaporize kerosene are either to have some arrangement in the carbureter for heating the mixture so as to gasify it before it enters the cylinder, or to use some device for spraying the oil into the cylinder in a liquid form where it is vaporized by the hot walls.

35. A cross-sectional view of a carbureter provided with a device for heating the fuel is shown in Fig. 10, which illustrates the Knox combination gasoline and kerosene carbureter. The fuel enters the float chamber *a* through the inlet *b* and is kept at a constant level by the float *c*. It then flows up through the passage *d* to the nozzle *e*, which is closed by the needle valve *f*. It is drawn through the nozzle *e* into the chamber *g* by the suction of the air moving up through the opening *h*. The fuel vapor and air become mixed in the chamber *g* and are then drawn into the engine cylinder through the opening *i*. The throttle valve is controlled by the lever *j*, and the air-inlet valve by the lever *k*.

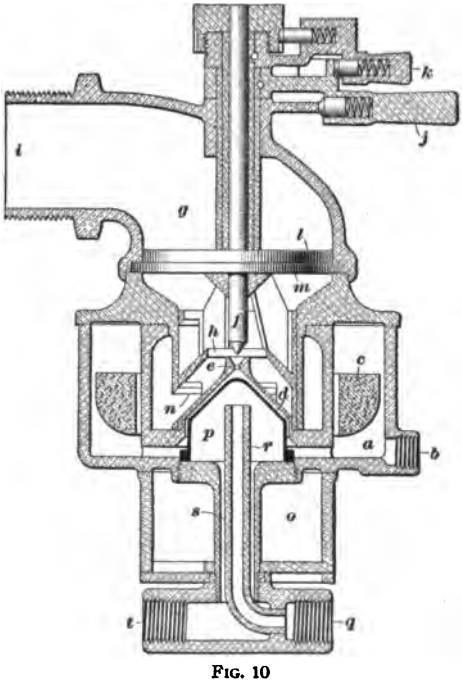


FIG. 10

In this carbureter the throttle valve is a shutter valve consisting of the movable disk *l* and the fixed disk *m*. These contain slots that can be made to register with each other by

turning the lever *j*. When the slots register, the valve is open and allows the mixture to enter the chamber *g*, but when the slots do not register, the valve is closed. The auxiliary air valve, located at *n*, is also a shutter valve consisting of a cylinder that works inside of a cylindrical passage. As the cylinder is turned to the right or left, the ports are opened or closed. The main air intake is at *o*.

36. The distinguishing feature of the carbureter shown in Fig. 10 is the use of the heating chamber *p* and the passages leading to and from this chamber. When kerosene is used as fuel, hot gases from the engine cylinder enter the carbureter at *q* and pass up into the heating chamber through the tube *r*, and thence out through the passage *s* and the outlet *t*. The kerosene is heated as it flows up around the heating chamber *p* and is readily vaporized at the nozzle *e*. The inlet *b* is provided with a three-way valve, one opening of which is connected to a gasoline cup placed above the carbureter and a second opening to the kerosene feed-tube. Gasoline may then be used for starting the engine and the kerosene turned on after the chamber *g* has become sufficiently warm to vaporize the oil. When gasoline is to be used exclusively, the heating chamber need not be connected up and the inlet *b* should be connected up with the gasoline tank.

37. A device for spraying liquid kerosene into the cylinder of an engine is shown in Fig. 11, applied to a two-port, two-cycle engine. The piston *a* is shown at the bottom of its stroke, the inlet port *b* and the exhaust port *c* being open.

The kerosene is led into a float chamber *d* through the needle valve *e*, which is controlled by the float *f* so that the fuel maintains a constant or nearly constant level. The float chamber is connected by a pipe *g* to a spray nozzle *h*, which extends into the inlet port *b* to within $\frac{1}{32}$ inch of the inside of the cylinder wall. The opening into the spray nozzle is regulated by the needle valve *i*. An open connection *j* is made between the float chamber *d* and the transfer passage *k*, by means of which the pressure in *d* is kept the same as that in the crank-case. When the port *b* is uncovered by the piston, oil is sprayed from

the nozzle *h* into the cylinder along with the air from the crank-case. When this device is used, air only is taken into the crank-case through the crank-case inlet port and forced into the cylinder through the transfer port.

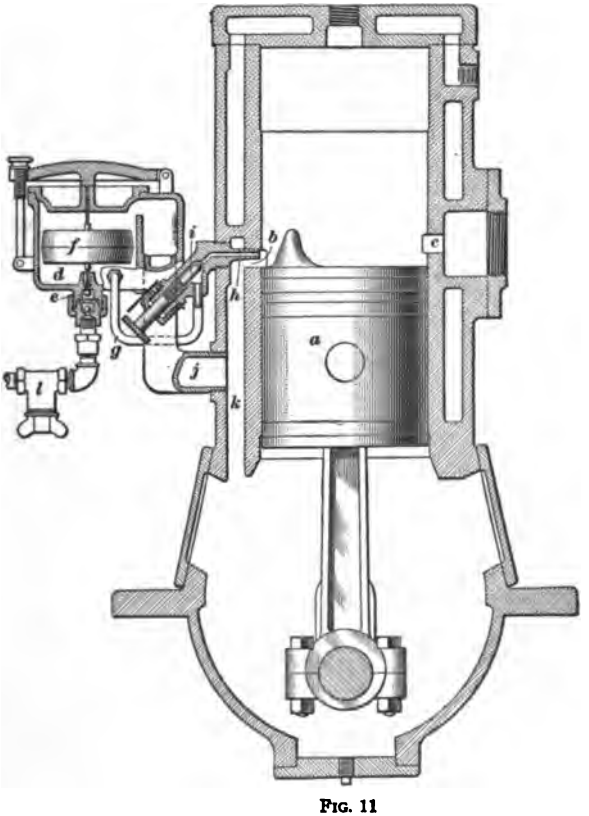


FIG. 11

38. The kerosene-fuel feed shown in Fig. 11 is used in connection with a gasoline carbureter, so that the engine can be started on gasoline and run until the cylinder walls become hot enough to vaporize the kerosene. A kerosene strainer for removing sediment and other foreign matter from the fuel is located at *l* in the fuel pipe.

PREHEATING OF AIR SUPPLY

39. Necessity for Preheating of Air.—The gasoline delivered from the nozzle of a carbureter is in the form of a mist or spray, and the fineness of the particles depends largely on the effectiveness of the nozzle. When the spray produced is very fine and the air supply has a temperature of 60° F. or greater, the gasoline will vaporize readily and a good mixture will be formed. But as the temperature of the air is frequently much below 60° F., to insure perfect vaporization it is necessary to supply heat from an external source. Sometimes the vaporizing chamber is water-jacketed, but a common method is to draw the air supply over the hot exhaust pipe from the engine. A part of the heat in the exhaust gases is thus transmitted to

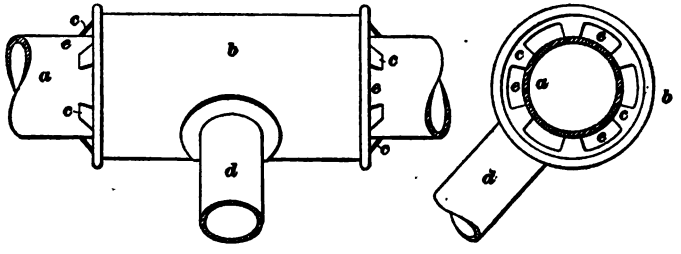


FIG. 12

the air supply and is carried by the latter into the carbureter, thus insuring rapid vaporization.

40. Heating of Air by Exhaust Gases.—A method of preheating the air supply to the carbureter by making use of the hot gases exhausted from the engine is shown in Fig. 12. Around the exhaust pipe *a* is fitted a short sleeve *b*, the inside diameter of which is considerably greater than the outside diameter of the exhaust pipe. The sleeve is held away from the pipe all around by the lugs *c*, and thus a space is formed inside the sleeve, surrounding the exhaust pipe. One end of pipe *d* is attached to the sleeve and the other end is joined to the main air intake of the carbureter. Under the effect of the suction in the carbureter, air is drawn in between the sleeve and the exhaust pipe through the openings *e*, and is heated by

direct contact with the hot exhaust pipe. It then flows through the pipe *d* to the carbureter, where the heat that it has absorbed is utilized in producing more thorough vaporization of the gasoline spray.

ELECTRIC IGNITION

BATTERIES

41. Sources of Electricity.—The combustible mixture in the cylinder of a marine gasoline engine is ignited by means of an electric spark that is produced in the combustion space. The electricity for producing this spark is obtained by chemical action from an electric battery, or by a power-driven machine called an electric generator.

The electric batteries used for ignition purposes are of two distinct classes: *primary batteries* and *secondary*, or *storage*, *batteries*. Secondary batteries are also known as *accumulators*. The primary battery will deliver electric current as soon as its parts are assembled, but with the storage battery, electricity from some separate source of supply must be stored in it before it becomes electrically active.

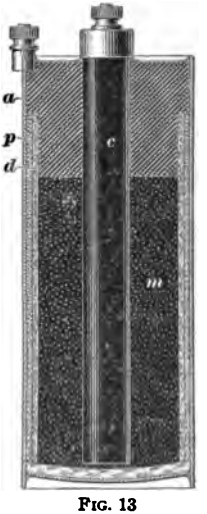


FIG. 13

Primary batteries are also divided into two classes: *dry-cell batteries* and *wet-cell batteries*. A dry-cell battery is made up of cells that contain no free body of liquid. A wet-cell battery is made up of cells that contain a free body of liquid. Wet cells are not used to any extent for marine-engine ignition because they are liable to become broken, are too bulky, and the liquid is liable to be splashed out.

42. Dry Cells.—Fig. 13 shows a section of a dry cell used for motor-boat ignition. The carbon rod *c* is placed in the center, and the zinc forms the enclosing cup or can *a*. Next to the can is a lining *p* of absorbent paper that is com-

pletely saturated with a liquid electrolyte consisting of sal ammoniac and zinc chloride dissolved in water, and next to the paper is a thin layer *d* of white paste. The space between the carbon rod and the lining of the cup is filled, except at the top, with the depolarizer *m*, which is a mixture of powdered carbon or coke and manganese dioxide. The cell is sealed watertight with pitch or some similar substance, which fills the space above the depolarizer, and is permanently wrapped, except over the top, with pasteboard and paper, to prevent metallic contact with other cells in a battery.

The positive terminal is at the center of the top, and the negative terminal is a binding screw attached to the top edge of the zinc cup. The cell generally used for motor-boat ignition is 2½ inches in diameter and 6 inches long. Dry cells similar in general appearance to this but differing in some of the materials employed, are also extensively used.

Dry cells of the size just mentioned usually have, when new and in good condition, an internal resistance of from .1 to .7 ohm and an electromotive force of 1.3 to 1.6 volts. As a rule, the best dry cells will not remain in good condition more than 2 or 3 years and good results should not be expected from cells that have been kept in stock for 1 year.

43. Battery Connections.—When a number of cells are connected together, as is customary, they form an electric battery. Cells can be connected in two ways: either the positive (+), or carbon-plate, terminal of one cell can be connected to the negative (−), or zinc-plate, terminal of the next, or similar terminals can be connected together. Both of these arrangements will give more current than will a single cell under any condition. In the first arrangement they are said to be *connected in series*, and in the second they are *connected in parallel*, or *multiple*.

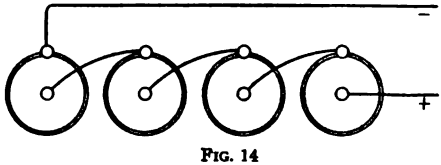


FIG. 14

A battery connected in series is shown diagrammatically in Fig. 14, the center terminals representing the carbon terminals

and the outside terminals representing the zinc. The positive terminal of one and the negative terminal of another cell become the terminals of the battery.

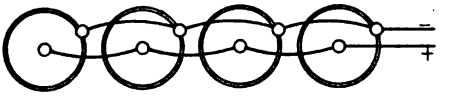


FIG. 15

44. If two or more cells are connected in parallel, carbon to carbon and zinc to zinc, the carbon side will be the positive terminal and the zinc side the negative terminal, as shown in Fig. 15. When a battery is connected in this manner, the voltage remains the same as for one cell, but when cells are connected in series, the battery voltage is equal to the sum of the voltages of the cells.

If two series batteries of the same number of like cells are connected in parallel, they form a multiple-series connection; such a connection is shown in Fig. 16. The voltage of such a battery is the same as that of one series. Each series of cells forming a unit should have the same number of cells, otherwise the higher voltage of the series having the greater number of cells will force current back through the series having the smaller number and exhauts the cells in the larger series.

It is customary to use a battery of from four to six dry cells in series. However, longer life may be obtained by connecting them in multiple series, when twice the number of cells should be used.

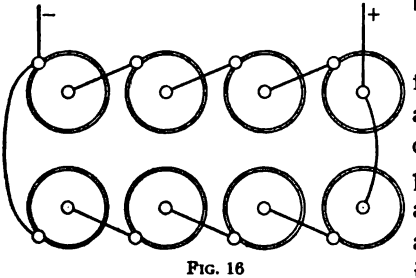
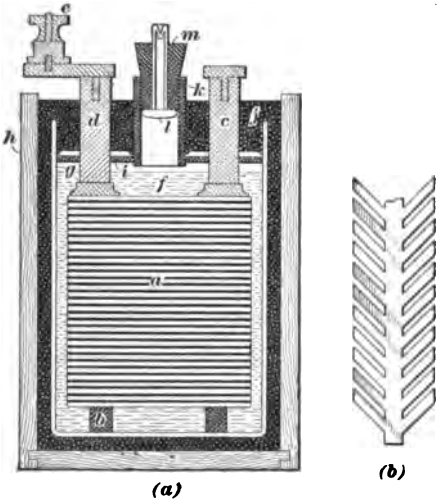


FIG. 16

45. Storage Batteries.—The activity of a storage battery, accumulator, or secondary battery depends on internal chemical action produced by passing an electric current through it from some external source of supply. This operation is called *charging* the battery. After the battery is charged, it will discharge through a closed circuit nearly the same quantity of electricity as was used to bring about the original chemical action. The positive terminal of a storage battery is the one by which the charging current enters

and the discharging current leaves. The majority of storage batteries used for electric ignition may be called *lead accumulators*, as lead and its oxides enter most prominently into their construction. In some of the types of storage batteries iron and nickel are used instead of lead.

46. Fig. 17 (*a*) shows a sectional view of a small storage battery made for marine-engine ignition purposes. At *a* is shown the side of the positive plate supported on hard-rubber insulators *b*, and in (*b*) is shown an enlarged end view of the same plate before forming. When the plate has been electro-chemically formed, all the grooves are filled with oxide of lead. The other parts of the cell in (*a*) are as follows: At *c* is shown the positive terminal and at *d* the negative terminal carrying a binding post *e*; at *f*, the electrolyte contained in a hard-lead jar *g*; at *h*, a hardwood case; and at *i*, a hard-rubber cover fitting tightly in the lead case; at *j*, a sealing compound filling the space between the lead jar and the hardwood case and also the space over the cover; and at *k*, a hard-rubber tube that contains a glass valve *l* and is closed by a rubber stopper *m*.



(*a*) (*b*)

FIG. 17

The cell is so effectually closed that it can leak but little, even if turned upside down. The solution used in a storage cell can be made semidry either by using an absorbent or by introducing some substance, such as a silicate of soda, to form a jelly with the acid. There is, however, a tendency for a semidry storage battery to dry out completely and thus become useless; this is especially true in a warm locality.

47. A direct current must always be used for charging the storage battery. In case only an alternating current is available, an alternating-current rectifier of some kind must be used for changing it into direct current.

The voltage of a storage cell varies from about 2.5 when fully charged to about 1.7 when completely discharged. The pressure falls rapidly about $\frac{1}{10}$ volt when the battery first begins to discharge after being fully charged. When the voltage has dropped to about 1.7 per cell, the battery should be recharged, because it retains only a comparatively small amount of electric energy at this pressure, and the voltage drops rapidly during discharge after getting this low. The life of the battery is shortened by discharging below 1.7 volts per cell.

Storage batteries for ignition purposes are generally made up of either three cells in series, giving an average pressure during discharge of about 6 volts, or two cells in series, with an average discharge pressure of about 4 volts. These two pressures are adapted to meet the requirements in operating induction coils.

SPARK COILS

48. There are two distinct methods of forming a spark for ignition purposes by means of the electric current. One method employs a current of low voltage, such as that produced by an ordinary dry-cell battery, and the spark is obtained by making and breaking the circuit. Systems using this method are known as **low-tension**, or **make-and-break, ignition systems.** The other method makes use of a current of very high voltage and the spark is formed by causing this current to jump an air gap in a spark plug. Systems using this method are known as **high-tension**, or **jump-spark, ignition systems.**

49. While a spark can be obtained from an ordinary battery current in a low-tension system, it is possible to increase its intensity by making use of an **inductance**, or **kick, coil.** A kick coil consists of a single coil of wire wound about a bundle of soft-iron wires, known as the **core.** When a low-

tension, or low-voltage, current flows through such a coil, an action known as **self-induction** takes place, and any rapid change in the strength of the current is opposed. Consequently, when the circuit is broken, the current continues for a longer time across the space between the separated contact points; and when the points are separated quickly, the current also continues across a longer space or a wider gap. By using such a coil with a battery, a spark may be produced that is hot enough to ignite a combustible gaseous mixture. A kick coil, suitably mounted, is shown in Fig. 18.

50. In a high-tension system of ignition, a very high voltage is required to cause a spark to jump the air gap, hence when only current of low voltage is available, such as a battery current, it is necessary to employ some means for converting the current into high-tension current. In marine-engine ignition, an **induction coil** is used for this purpose. An induction, or jump-spark, coil consists really of two coils of wire, one wound about the other, and the whole surrounding a core composed of a bundle of soft-iron wires. The inner, or primary, coil is made up of a few turns of coarse, insulated wire, while the outer, or secondary, coil is made up of a large number of turns of fine, insulated wire.

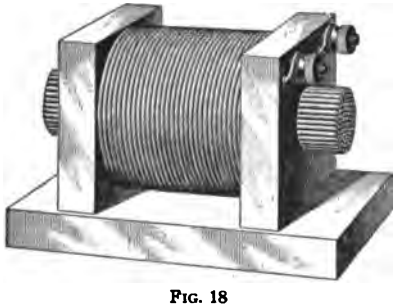


FIG. 18

If a current of low voltage is caused to flow through the primary coil and then stopped suddenly, a high-tension current is set up in the secondary winding. A high-tension current is also induced when the primary current is suddenly increased. In practice, the battery current is run through the primary winding and the circuit is repeatedly broken by means of a magnetic vibrator or an interrupter. The secondary winding is connected to the spark plug or spark plugs, and a high-tension current carried to the spark gap or gaps at regular intervals.

51. In Fig. 19 is shown a typical jump-spark coil enclosed in a wooden box *a*. The coil proper consists of the core *b*, the primary coil *c*, and the secondary coil *d*. The coil is provided with the magnetic vibrator *e*, which automatically makes and breaks the primary circuit. The battery or low-tension magneto is connected to the low-tension terminals *f* and *g*, hence the current must pass through the vibrator *e* and the bridge *h* in order to flow through the battery. With the vibrator in the position shown, the circuit is closed and a current will flow through the primary coil *c*. As soon as a current flows through the coil *c*, the core *b* becomes magnetized and the soft-iron piece *i* draws the vibrator to it, separating the vibrator points at *j* and breaking the primary circuit. This

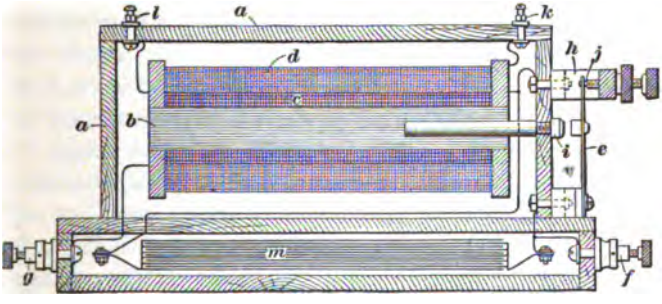


FIG. 19

operation induces a secondary current of high voltage in the secondary coil *d*, which is connected to the external circuit by means of the terminals *k* and *l*. One of these secondary terminals is usually connected to the spark plug and the other to the engine frame, thus completing the secondary circuit.

52. When the contact at *j* is broken, a spark is formed at that point if no provision is made to prevent it. For the prevention of such a spark, with the accompanying injury to the contact points, a condenser *m* is connected around the point *j*. The condenser consists of alternate layers of tin-foil and waxed paper and has the property of storing up electric energy; hence, when the contact points are separated, the current flows back into the condenser instead of forming an arc over the space.

Thus, a spark is prevented and the primary current stopped more suddenly, which causes a stronger secondary current to be produced. The energy stored in the condenser is given back to the primary circuit.

ELECTRIC GENERATORS

53. Classification.—The electric generators commonly employed for ignition purposes are divided into two principal classes, namely, those that generate a continuous, or direct, current, and those that generate an alternating current. The former are known as *direct-current generators*, *dynamo-electric generators*, or simply *dynamos*. The latter are known as *magneto-electric generators*, or simply *magnetos*. There are two classes of magnetos: (1) those that generate a low-tension current for the make-and-break type of ignition system and for delivery to both vibrator and non-vibrator induction coils, by which the low-tension primary current is transformed into a high-tension current, which is led to the spark plugs by the heavily insulated secondary wiring, and (2), those that generate a high-tension current, embodying within themselves all the elements necessary to the production and distribution of such current, thereby making the use of induction coils unnecessary.

54. Essential Parts of an Electric Generator.—As the simplest mechanical motion is rotation, electric generators use this principal for sweeping the conductors through the magnetic field. There are essentially two parts to such a machine: the *field magnet*, wherein is produced the necessary magnetism; and the *armature*, on or near whose surface the working conductors (those that cut the lines of force) are arranged. These two parts are rotated relatively to each other, it being immaterial, except for convenience, which is stationary and which is rotated.

A single conductor can seldom be made to generate a desired voltage, so that on an armature a number of conductors are usually connected up in series and in parallel, in the same way as electric batteries, until the required voltage and current-carrying capacity are obtained.

55. Dynamos.—The field magnets of a dynamo may be permanent magnets or electromagnets. As a usual thing, they are electromagnets and consist of soft iron wound with wire, through which current flows, thus magnetizing the iron. Ignition dynamos are generally of the self-exciting, shunt-wound type, the magnetizing current being obtained from the dynamo itself. The armature core is usually cylindrical in shape and built up of disks of the proper size punched from sheet iron. This core is then wound lengthwise with a number of coils of wire in which the current is produced when the armature is rotated. The current is collected from the armature winding by means of copper brushes.

A diagrammatic view of a typical shunt-wound dynamo is shown in Fig. 20. The armature *a* rotates between the magnet poles *b*, and the current is collected by means of the brushes *c*. The copper segments *d* rotate with the armature and are called commutator bars. As the ends of the coil wound on the field magnet are connected to the brush terminals, the field coil forms a shunt, or by-pass, for part of the current delivered by the armature. The remainder of the current flows through the external circuit *R*, which in this case consists of the wiring of the ignition system.

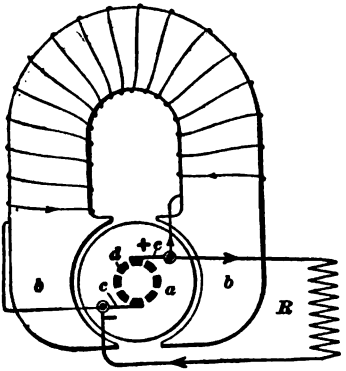


FIG. 20

56. A dynamo must usually run at very high speeds in order to generate enough current for ignition purposes and, therefore, is not efficient at low speeds. On account of this fact, the dynamo is ordinarily used in connection with a storage battery. The generator and battery are so connected that they operate in conjunction with each other; that is, the system is so wired that when running at average or high speeds the dynamo supplies the current and keeps the storage battery charged, but when running at low speed the storage battery

furnishes the current. A system connected up in this manner is known as "floating the battery on the line," and is used largely for supplying current for electric lighting as well as for ignition. In actual practice, the dynamo is driven from the engine by gears, friction wheels, or belting. The advantage of this system is that current for lighting may be furnished even when the engine is not running, and there is usually sufficient charge in the battery to get back to port should the dynamo fail.

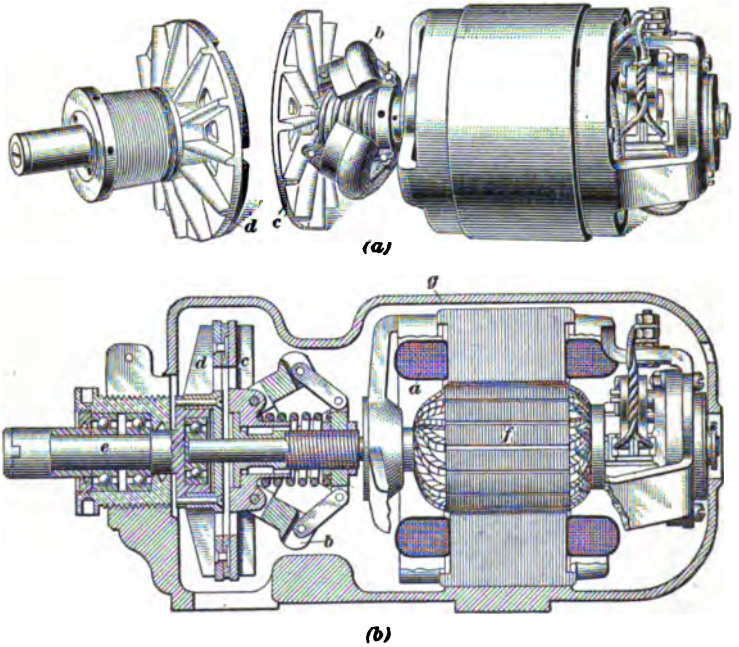


FIG. 21

57. In Fig. 21 is shown a dynamo such as is used for electric ignition and lighting purposes, (*a*) being an outside view and (*b*) a longitudinal section. It is of the compound-wound type, that is, part of the field coils *a* is connected in shunt with the dynamo and part is connected in series with the external circuit. As the machine is designed to run at 1,200 revolutions per minute, the speed is regulated by a simple centrifugal governor *b* that releases the members *c* and *d* of a friction clutch when the

speed increases and engages them when the speed decreases. The dynamo is driven from the engine by the shaft *e*. The armature of the dynamo is shown at *f*, and the whole is enclosed in a casing *g*, to protect the parts from dust and oil.

58. Magnetos.—The field magnets used in magnetos are permanent magnets and as a rule are **U**-shaped, although on one make of magneto a bell-shaped magnet is used. The armature core is of soft iron and generally shaped like the letter **H**, having wound on it a coil of many turns of fine insulated wire. The coil is arranged to rotate between the poles of the permanent magnet. A diagrammatic view of such a generator is shown in Fig. 22. The armature *a* rotates between the pole pieces *b* attached to the poles *N* and *S* of the magnet. Current is generated in the winding and delivered to the external circuit by the wires shown.

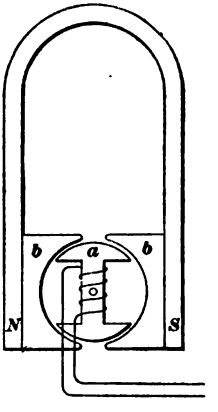


FIG. 22

Such an instrument generates an *alternating current*, that is, the current flows in opposite directions, alternately. Dynamos generate a *direct current*, or one that flows in a continuous direction. The current produced by a battery is also direct current. Alternating or direct current may be used for ignition purposes with equally good results.

59. A low-tension magneto is one that generates a current of low voltage, such as is used for contact ignition, or for the primary winding of a spark coil. The current obtained by such an instrument is not strong enough to produce a spark by jumping the gap in a spark plug, but must either have its voltage increased by means of an induction coil or be used in connection with an igniter, which forms a spark by making and breaking the circuit. Batteries and dynamos also produce a current of low tension, or low voltage.

60. A typical low-tension magneto, designed for use with a four-cylinder engine is illustrated in Fig. 23, which shows

three views of the Splitdorf, model X magneto, (*a*) being a perspective view, (*b*) an end view, and (*c*) a longitudinal section. The same parts in the various views are lettered the same in order to show their location. The magneto contains two sets

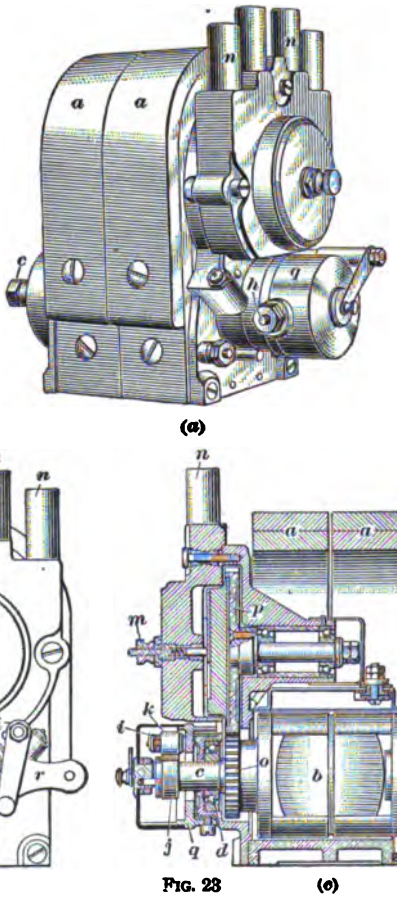


FIG. 23

of magnets *a* between which the armature *b* is rotated by means of gears from the engine crank-shaft. This armature is carried on a shaft *c* that rotates in the ball bearings *d*. The armature winding *b* consists of a single coil of fine wire. As it turns between the magnets, an electric current is set up in the winding

and is carried by the shaft *c* to the slip ring *e* from which it is delivered to the terminal *f* by means of a carbon brush *g*.

From *f* the current flows through an induction coil back to the terminal *h* on the magneto. This terminal is normally electrically connected with the armature winding through the arm *i*, and, therefore, where the arm is in the position shown, a complete circuit is formed and a current flows through this circuit. But when the cam *j* turns so that it lifts the arm *i* by the roller *k*, the contact points at *l* are separated and the flow of current is stopped. This breaking of the circuit, which occurs twice during each revolution of the armature, causes a high-tension current to be set up in the induction coil. This high-tension current is then led to the distributor terminal *m*, and is delivered to the spark plugs at regular intervals through the terminals *n*. The distributor, which is driven from the shaft *c* by the gears *o* and *p*, consists of an arm that rotates and makes regular contact with the four terminals *n*, thus delivering the current to them from the center terminal *m*.

61. The parts enclosed in the casing *q* form the circuit-breaker. The arm *i* and terminal *h* are carried by this casing so that any movement of it will vary the time at which the circuit is broken and a high-tension current formed. Rotating *q* in one direction, by means of the arm *r*, retards the spark, and rotating it in the other direction advances it. The exact direction in which the casing is rotated depends on the direction of rotation of the armature shaft.

62. A **high-tension magneto,** strictly speaking, is a magneto that delivers electric current of sufficiently high voltage, or tension, to jump the gap of a jump-spark plug under the usual conditions of operation, the high-tension current being produced and delivered without using any auxiliary coils or wiring separate from the magneto. The high-tension magneto performs all the functions of an electric generator, a timer, a spark coil, and, for the usual case of four or more cylinders, a distributor. It is really the embodiment of all these individual parts in a single piece of apparatus. A current of high voltage is obtained by the use of two windings, a primary

and a secondary, on the armature. A low-tension current is first generated in the primary winding and this is converted into a high-tension current in the secondary winding in the same manner that an induction coil produces a current of high voltage.

63. The Bosch high-tension magneto, designed for use with a single-cylinder engine, is shown in Fig. 24, in which (*a*) is an

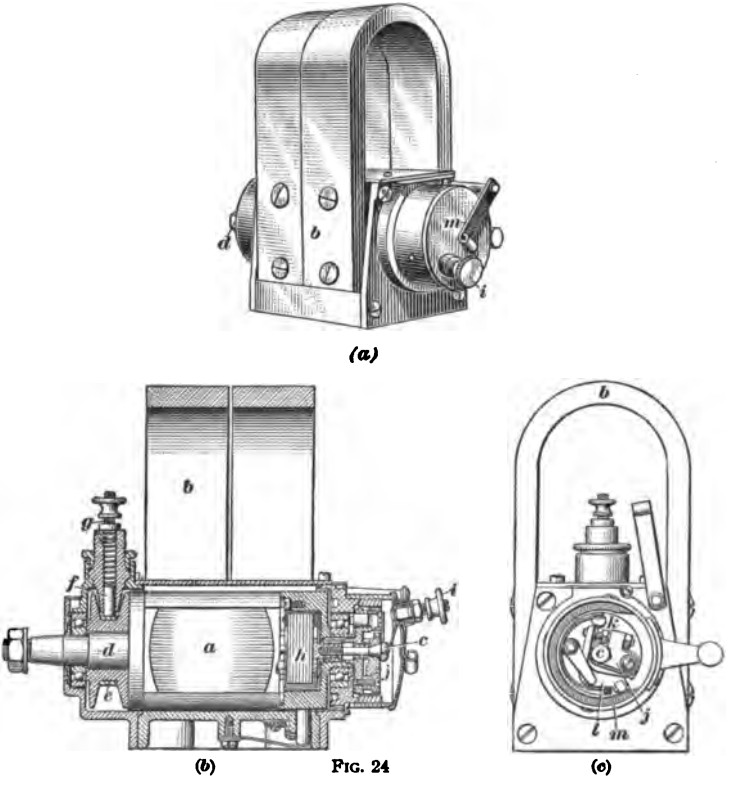


FIG. 24

external view, (*b*) a longitudinal section, and (*c*) an end view. The armature *a* consists of a primary winding composed of a few turns of heavy wire, and a secondary winding composed of a great number of turns of very fine wire. As the armature rotates between the steel magnets *b*, a low-tension current is

set up in the primary winding. This current is conducted by the screw *c* to the circuit-breaker when it is interrupted once during each revolution of the magneto shaft *d*. The interruption of the primary current causes a current of high voltage to be produced in the secondary winding. This high-tension current is led to the slip ring *e*, by a connection from one end of the secondary winding, and is collected by the brush *f* and delivered to the ignition system through the terminal *g*. A condenser *h* is connected in the primary circuit to prevent burning of the circuit-breaker contact points and to strengthen the secondary current. The terminal *i* is for the purpose of connecting the primary circuit to a switch, by means of which the circuit may be opened and the magneto made inoperative.

64. The circuit-breaker in the magneto takes the place of the vibrator in the induction coil. The screw *c* and the block *j* are insulated from the interrupter disk *k*, which is electrically connected to the armature coil. The interrupter contact block *j* carries a platinum contact screw fitted with locknuts. The interrupter lever *l* is in the form of a bell-crank and carries on one end a platinum screw that is held in contact with the one in the block *j* by a spring. The interrupter lever is electrically connected to the armature core and hence to one end of the primary winding, which is thus short-circuited as long as the platinum screws of the contact block and interrupter lever are in contact. The interrupter housing *m* can be rotated to advance or retard the spark; it carries a steel cam that, through coming in contact with one end of the interrupter lever *l*, breaks the contact between the screws of the interrupter lever and contact block *j*, thereby suddenly breaking the primary circuit.

65. A magneto of this type designed for use with two cylinders contains two interrupter cams located opposite each other, and is provided with two secondary terminals, so that a high-tension current may be obtained twice during each revolution of the magneto shaft. For engines of more than two cylinders, a single high-tension terminal is used and the current is led from this to a distributor, usually a part of the

magneto, by means of which it is delivered to the various cylinders. The speed at which a magneto runs depends on the construction of the engine, although it must always bear a fixed relation to the engine speed. For instance, for a single-cylinder four-cycle engine, the magneto is driven at one-half crank-shaft speed, as only one explosion occurs for every two revolutions of the crank-shaft; while for a single-cylinder two-cycle engine, the magneto is driven at crank-shaft speed. On two-cylinder four-cycle engines with cranks set side by side, the explosions in the two cylinders will occur one revolution of the crank-shaft apart, and the armature of the magneto is therefore driven at one-half crank-shaft speed, assuming that the magneto is designed for two-cylinder engines and gives two sparks per revolution of the armature. Magneto armatures are usually driven by spur gears or helical gears, although in some cases silent chains are used for this purpose.

IGNITERS AND SPARK PLUGS

66. Igniters.—The sparking device employed with the low-tension, or make-and-break, system of ignition is called an **igniter.** The make-and-break system uses a low voltage current obtained from a battery or low-tension magneto, and the purpose of the igniter is to break the circuit inside of the cylinder and thus cause a spark to be formed. Igniters are of two general types, *mechanical* and *magnetic.* A mechanical igniter is operated from some moving part of the engine by mechanical means, while a magnetic igniter is operated by means of an electromagnet that receives its current from the ignition system.

67. A **mechanical igniter** with the mechanism for actuating this and similar devices, is shown in Fig. 25, view (*a*) being a front elevation and view (*b*) a side elevation. At *a* is shown a shaft turning at one-half the speed of the engine if it is of the four-cycle type, or at the same speed if it is of the two-cycle type; in this case it may be the engine crank-shaft itself. On this shaft is a cam *b*, frequently called a *snap cam,*

that bears against a roller *c* held in contact with the cam by the spring *d* on the tappet rod *e*. The lower end of this rod, or plunger, is threaded, so that by adjusting the nuts at *f*, and thus increasing or decreasing the distance that the foot of the rod extends into the socket *g*, the length of the rod and, consequently, the width of the gap when the igniter points separate, can be varied at will.

When the roller *c* is in its lowest position, the ball on the upper end of the tappet rod *e* rests in a socket in the lever arm *h*. This arm is secured to a rocking stem that passes through the wall of the combustion chamber, as shown by the dotted lines of the side elevation. The inner end, which has a ground joint to prevent the gases from blowing past it, is prolonged to the finger *i*. This finger makes contact with an insulated stem *j*, to whose outer end one of the wires of the electric circuit is attached. A light spring *k* holds the finger *i* against the stem *j*, except when the two are separated by the pull of the head of the tappet rod *e* in the socket of the arm *h*. Because the greater tension of the spring *d* overcomes that of the spring *k*, the contact points are normally out of contact except when the tappet rod is pushed up by the cam. The adjustment of the tappet rod is such that after contact has been made it leaves the socket of the arm *h* and continues its upward motion a short distance, so that, when the roller *c* drops off from the cam, the

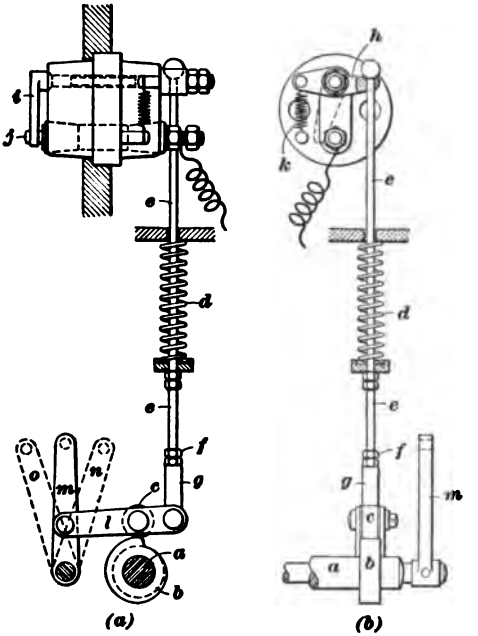


FIG. 25

head of the tappet rod strikes the arm *h* a smart blow, thereby causing an abrupt separation of the contact points.

As shown, the roller *c* is mounted in a rocker-arm *l*, one end of which is pin-connected to a second rocker-arm *m*, which is operated by hand to control the time of ignition. When the arm *m* is moved toward the right, as indicated by the dotted outline *n*, the ignition is earlier than when it is in the position *m*; when *m* is moved toward the left, to the other dotted position *o*, the ignition is made later.

68. A magnetic igniter designed to be operated on current from a battery or a low-tension magneto, is illustrated in Fig. 26, in which (*a*) is an external view and (*b*) a longitudinal section. The hexagon-headed plug *a* is screwed into the engine cylinder and a wire from the battery or magneto is connected to the terminal at the top. The body *b* of the plug contains a spool-wound magnet coil *c* and the upper end of the interrupter lever *d*. The igniting current passes through the magnet coil, and moves the interrupter lever so as to break the circuit and form a spark at the contact points of the igniter. When the current flows through the coil, the core *e* is magnetized and a magnet pole is thus formed in the region of the brass insert *f*. This pole attracts and draws toward it the upper end of the interrupter lever *d*, thus rocking the lever on its knife-edge support and moving the contact point *g* away from the point *h*. This breaks the electric circuit and causes a spark

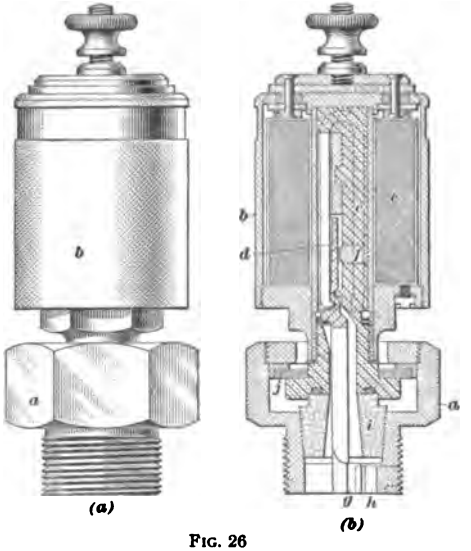


FIG. 26

at the contact points, which extend inside of the combustion chamber. The body *a* is insulated from *g* by the steatite cone *i* and mica plates *j*.

69. Spark Plugs.—The universal method of obtaining a spark with the high-tension system of ignition, which uses a current of high voltage, is by means of a spark plug. The

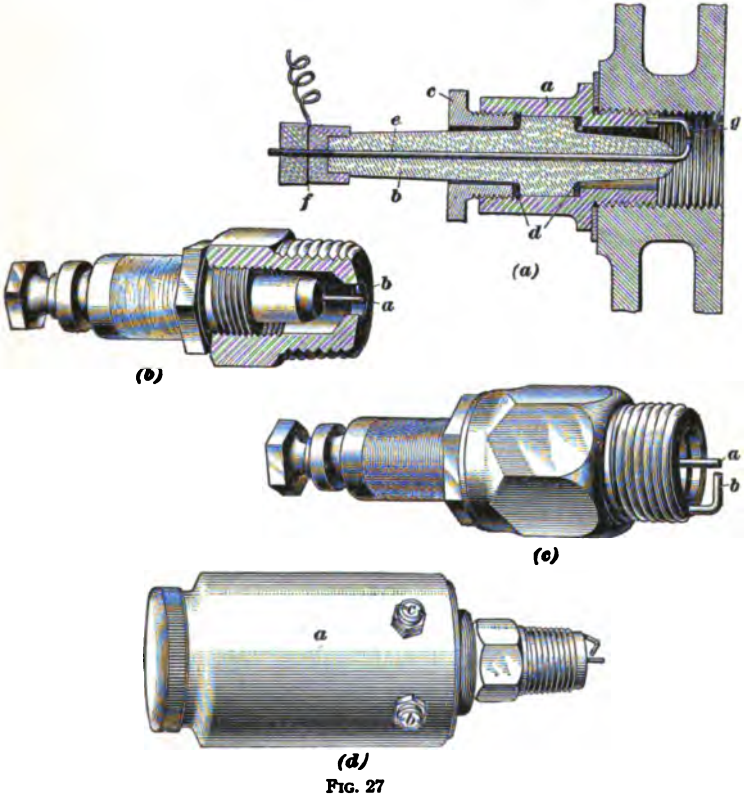


FIG. 27

spark plug consists of a small wire or rod that passes through some kind of insulating material and to within a short distance of a threaded piece of metal or bushing that surrounds the insulation. The space left between the wire and the outer metal bushing is the gap across which the spark jumps. This gap is usually from $\frac{1}{64}$ inch to $\frac{1}{32}$ inch, depending on the strength

of the high-tension current. The high-tension circuit is completed through the central wire, the gap, and the metal of the engine cylinder.

70. Some typical spark plugs are shown in Fig. 27. In (*a*), the steel bushing *a* that screws into the threaded hole in the engine cylinder contains the porcelain insulator *b*, which, with its packing, is held in place by a threaded bushing *c*. The insulator is separated from the metal by a packing ring of copper, asbestos, or some other suitable material *d* and it contains an insulated wire, or electrode *e*. A binding-screw terminal for connecting the external wire is provided at *f*. The spark gap is between the curved end of the central insulated wire *e* and the grounded wire *g* projecting from the bushing *a*.

The construction of the plugs shown in (*b*) and (*c*), differs but little from that shown in (*a*). What is known as a *closed-end plug* is shown in (*b*), the points *a* and *b* being located in the nearly closed end of the plug. The point *a* is concentric with the plug-end opening, into which the point *b* projects from one side. The so-called *open type* of the same plug is shown in (*c*), the point *a* projecting beyond the end of the plug, as shown. The point *b* can be turned away from *a* to increase the gap between the points.

A waterproof spark plug especially valuable for use on marine engines is shown in (*d*). The feature of this spark plug is that the upper part consists of a waterproof casing *a* that contains a vibrator, condenser, and induction coil. The plug is connected in the low-tension circuit of an ignition system at the terminals *b* and *c* and its action is like that of an ordinary plug. A separate condenser, vibrator, or induction coil is of course unnecessary with this apparatus.

IGNITION SYSTEMS

71. Classification.—A low-tension ignition system is a system in which a current of low voltage is used and the spark is produced by means of a make-and-break igniter. The current may be obtained from a primary battery, storage

battery, low-tension magneto, or a dynamo. A kick coil is connected in the circuit in order to secure a hot spark when battery current is employed. The most common source of current for this system is a dry battery.

A **high-tension ignition system** is a system in which a current of high voltage is used and the spark is produced by causing the current to jump the gap in a spark plug. The current may be obtained from any one of the low-tension sources, when an induction coil must be used to transform it to high-tension current, or from a high-tension magneto. The most usual source of current is a dry battery or a high-tension magneto.

72. A dual system of ignition is one that employs two separate sources of current, either of which may be used for supplying current to the igniters or spark plugs. One source of current is generally a battery and the other a magneto.

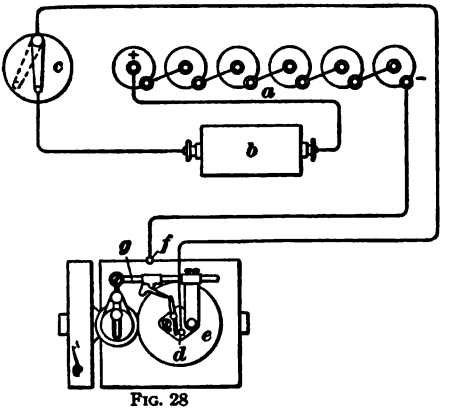


FIG. 28

A **double system** also contains two sources of current, but it differs from the dual system in that each cylinder is provided with two igniters or two spark plugs and both sources can be used at the same time, causing two sparks to occur in a cylinder at one time. In the double system, either source may be used alone, as in the dual. In some high-tension systems, a magneto that will give two sparks simultaneously is employed; such systems are known as **two-independent** or **double-spark** systems, and the magneto is known as a *two-independent magneto*.

A **duplex system** uses a magneto and battery in conjunction with each other and so connected that the battery current flows through the magneto-armature coils, thus using them as induction coils. In this system, the battery is only used for starting purposes.

The systems generally used in motor-boat ignition are the single system and dual system, although the double system is also coming into extensive use.

73. Low-Tension Systems.—A low-tension, single-ignition system using a dry battery and wired for a single-cylinder, marine engine is shown in Fig. 28. The positive (+) terminal of the battery *a* is connected through the kick coil *b* and the hand switch *c* to the make-and-break igniter *d* on top of the engine cylinder *e*. The negative (−) terminal of the battery is connected to the engine bed or frame *f*, thus forming the *ground*, or return, path for the current. With the switch *c* in its closed position, as indicated by the full lines,

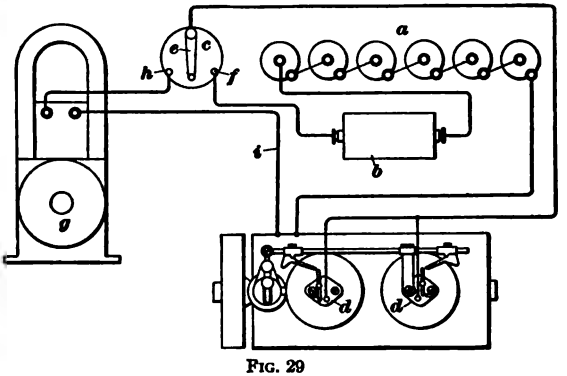


FIG. 29

and the igniter points located inside of the cylinder making contact, a current will flow from the positive terminal of the battery through the coil *b* and switch *c* to the fixed electrode of the igniter *d*. It then flows through the movable electrode of the igniter into the metal of the engine cylinder *e* and back to the negative terminal of the battery by way of the frame *f*. When the electrodes of the igniter are separated by a movement of the rod *g*, a spark is formed in the combustion chamber. The time at which the spark occurs may be changed by varying the time at which the rod *g* is operated. The rod *g* receives its motion from a vertical shaft geared to the engine crank-shaft. When the blade of the switch is placed in the position indicated by the dotted lines, the system is inoperative.

When an engine having two or more cylinders is wired for this system, the stationary electrode of each igniter is connected to the wire running from the positive terminal of the battery. As the electrodes are normally separated, except immediately before the spark is formed, current will flow through only one igniter at a time.

74. A dual, low-tension system for a two-cylinder engine, making use of a low-tension magneto and a dry battery, is shown in Fig. 29. A double switch is used in this system in order to connect up either the magneto or battery. The battery *a* is connected through the kick coil *b* and the switch *c* to the igniters *d* in exactly the same manner as shown in Fig. 28.

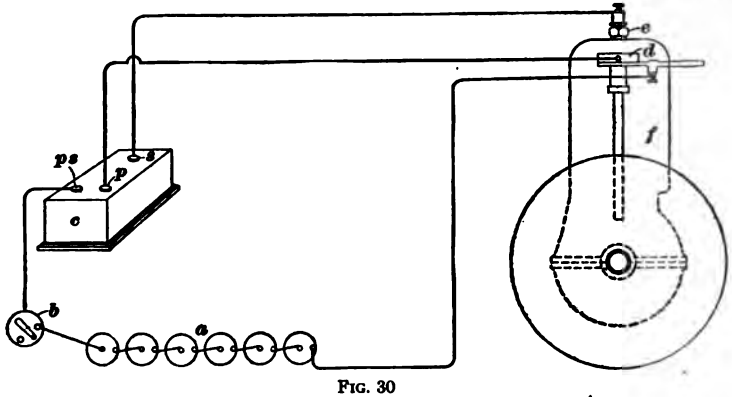


FIG. 30

One side of the magneto is connected to the switch and the other side to the engine frame. With the switch blade *e* in the position shown, no current flows from either source. When the blade is turned to the right over the terminal *f*, the battery *a* is connected in the system and the current acts as in the system just described.

The magneto *g* can be brought into the circuit by throwing the blade *e* over to the terminal *h*, when current will flow directly from the magneto to the igniters and back to the magneto through the ground connection *i*. The kick coil *b* is not connected in the magneto circuit, as the machine is designed to give sufficient current without a separate coil.

75. High-Tension Systems.—In Fig. 30 is shown a simple, high-tension, ignition system for a single-cylinder engine, using a dry battery as a source of current. In a system of this kind, there are two distinct electric circuits, namely, a low-tension, or battery, circuit and a high-tension circuit. What is known as a *three-terminal induction coil* is usually employed. Instead of having two separate secondary terminals, one end of the secondary winding is connected to one end of the primary winding and the two are attached to a single terminal called the *primary-secondary terminal*. On a coil box of this kind, there are a primary terminal, a secondary terminal, and a primary-secondary terminal.

In the present instance, the primary circuit consists of the battery *a*, the switch *b*, the primary winding of the induction coil *c*, the timer *d*, and the necessary wires. The secondary circuit consists of the secondary winding of the induction coil *c*, the spark plug *e*, the metal of the engine *f*, and the primary wiring from the timer through the battery to the coil.

When the switch *b* and the timer *d* are both closed and the primary circuit is completed, the current produced by the battery *a* flows from the positive (+) terminal through the switch *b* to the primary winding of the coil by way of the primary-secondary terminal *p s*. After flowing through the primary winding, the current returns to the negative (−) terminal of the battery by way of the primary terminal *p* and the timer and wire connections. The coil *c* is provided with a magnetic vibrator, which is not shown in the illustration. The rapid opening and closing of the primary circuit by the vibrator causes a current of high voltage to be set up in the secondary coil. This high-tension current flows by way of the secondary terminal *s* through the spark plug *e*, jumps the gap and forms a spark in the cylinder, and returns to the secondary winding through the battery and primary-secondary terminal *p s*.

76. It should be borne in mind that in order to have a current, there must be a complete circuit, whether it is a primary current or a secondary current. It is a property of electricity that one connection may form a part of two separate circuits

without the currents interfering with each other. Hence, in this case the secondary current can complete its circuit through the battery and not harm the battery current. This fact makes possible the three-terminal coil.

77. A timer used on high-tension ignition systems for single-cylinder engines is shown in Fig. 31, in which view (*a*) is a horizontal section and view (*b*) a vertical section. The timer contains a metal spool *a* that is fastened to the end of

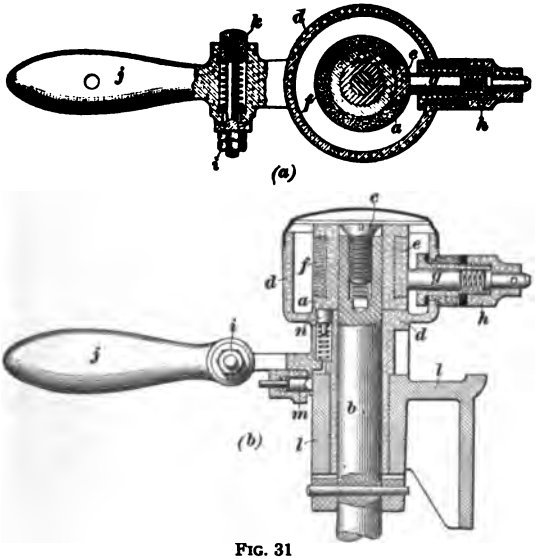


FIG. 31

the timer shaft *b* by means of a screw *c*, the end of the shaft being split. The shaft *b* is rotated from the engine crank-shaft and turns the spool in the body *d* of the timer. The spool *a* contains a copper segment *e* set in a fiber insulation segment *f*. A contact plunger *g* is set in an insulated binding post *h* and makes contact with the spool. A second binding post *i* is located on the handle *j* and so arranged that pressure on the insulated button *k* breaks the electric contact between the binding post and the handle. The complete device is supported by a bracket *l* from the engine frame, and a ratchet *m* is provided for regulating the movement of the handle *j*.

When the spool *a* is turned by means of the shaft *b* so that the plunger or brush *g* makes contact with the copper segment *e*, an electric circuit is completed through the spool and handle to the binding post *i*. The timer thus completes the primary circuit, in which it is connected by the two binding posts, and a current is set up in the secondary, as explained. The current is transmitted from the spool *a* to the handle *j* by means of a brush *n*. The electric circuit may be instantly cut out by pressing the button *k*, which pushes the binding post away from the handle.

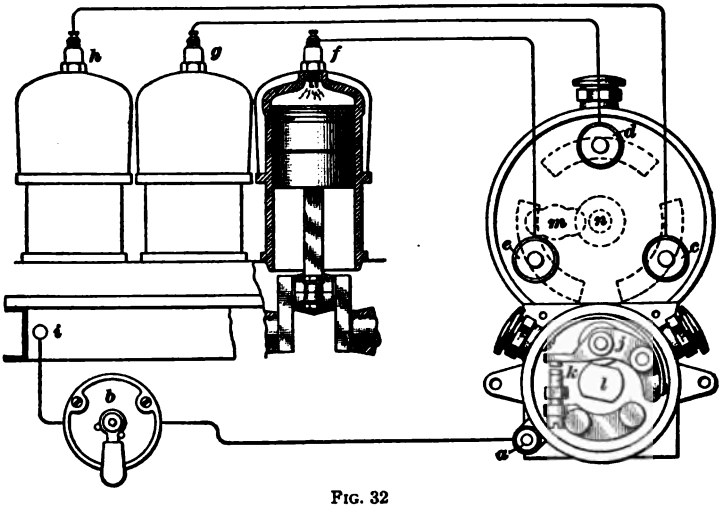


FIG. 32

78. Timers for multiple-cylinder engines are constructed on the same principle as that shown in Fig. 31, except that there are as many copper segments as cylinders. The time at which ignition takes place may be varied, or in other words, the spark may be advanced or retarded, by moving the handle to the right or left. This movement of the handle, and consequently of the body, of the timer changes the relative positions of the contact plunger and the copper segment, and causes electric contact to take place earlier or later in the rotation of the engine crank-shaft, thereby varying the time of ignition. On large engines the movable part of the timer is often connected

by means of rods and levers to the bulkhead of the boat, from where it is operated by means of a hand lever called the *spark lever*. In boats fitted with the so-called automobile type of steering gear, the spark lever is located on the steering wheel.

79. The wiring for a single, high-tension, ignition system for three cylinders, employing a high-tension magneto as the source of current, is shown in Fig. 32. The primary terminal *a* of the magneto is connected to the switch *b*, located on the bulkhead or other convenient point, and the secondary terminals *c*, *d*, and *e* are connected to the spark plugs *f*, *g*, and *h*.

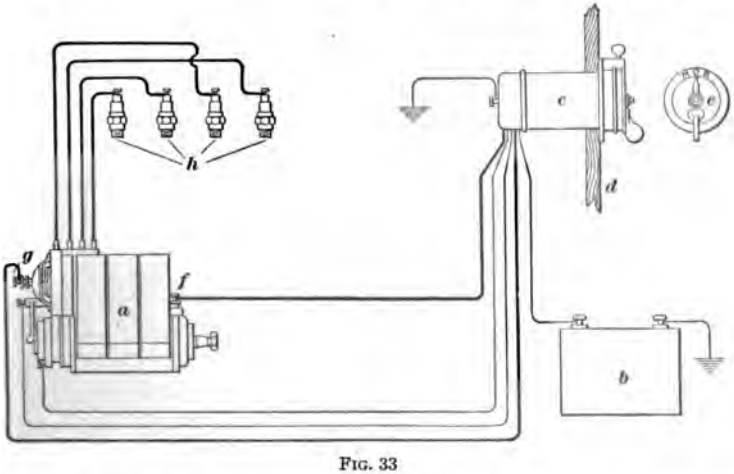


FIG. 33

The switch *b* is grounded to the engine frame *i* in order to complete the primary circuit. With the handle of the switch in the position marked *on*, the primary current generated in the primary winding of the magneto armature flows by way of the interrupter lever *j*, contact screw *k*, switch *b*, and engine frame *i* back to the magneto. The rotation of the cam *l* raises and lowers the lever *j* and thus opens and closes the primary circuit and sets up a high-tension current in the secondary winding of the armature. The high-tension current is delivered by the magneto distributor to the spark plugs from which it returns to the secondary winding by way of the engine frame.

The distributor is shown in dotted lines. The arm *m* is made to rotate by means of a shaft *n* driven from the regular magneto shaft. As the arm revolves, it makes electric contact with the segments connected to the terminals *c*, *d*, and *e*. These segments are set in insulation so that current will flow through only one at a time. The high-tension current flows from the secondary winding to the shaft *n* and arm *m*, and thence to the various segments and spark plugs as the arm revolves.

80. The Bosch high-tension dual ignition system is illustrated in Fig. 33. The sources of current are a Bosch high-tension magneto *a* and a dry-cell battery *b*. These are connected up, as shown, to a combined switch and induction coil *c* that is usually located on the bulkhead *d* of the boat. An end view of the switch showing the different positions of the handle is given at *e*. The coil *c* contains a vibrator and is for the purpose of transforming the battery current into high-tension current when the battery is used. The heavy lines in the diagram represent high-tension wires, and the fine ones represent low-tension wires.

When the pointer on the switch is at the position marked *M*, the battery circuit is cut out and current is supplied by the magneto *a*. The low-tension circuit of the magneto is completed through the switch and a high-tension current is generated. This current flows to the switch by way of the terminal *f* and the corresponding high-tension cable, through the switch and to the central distributor terminal *g* on the magneto. From the distributor, the current is delivered to the various spark plugs *h* and then returns to the magneto by way of the engine frame.

81. When the switch handle is set to the battery position, or that marked *B*, the primary circuit of the magneto is opened and the magneto generates no current. At the same time the battery circuit is completed and current flows from the battery, through the primary winding of the induction coil, and back to the battery by way of the ground connections. As the battery circuit is opened and closed by the vibrator, a current of high voltage is set up in the secondary winding of the induction coil. This high-tension current flows by way of the high-

tension wire to the central terminal of the magneto distributor and is delivered to the spark plugs in the regular way, returning through the engine frame to the grounded connection of the coil.

With the switch turned to the off position both magneto and battery circuits are opened and the entire system is inoperative.

82. Master Vibrator.—A high-tension ignition system for a multiple-cylinder engine making use of a battery as a source of current, may be provided with as many separate induction coils as there are cylinders and a high-tension wire running from each coil to a spark plug; or, it may be provided with a single coil and a separate distributor. The distributor for such a system operates on exactly the same principle as those incorporated in magnetos. When a number of coils are used, a **master vibrator** is often employed instead of a separate vibrator for each coil. The master vibrator consists of a separate magnetizing coil and core which operate a vibrator that is so connected in the system that it makes and breaks the circuit for each induction coil. This does away with the use of a number of vibrators and insures the same vibrator action for each coil.

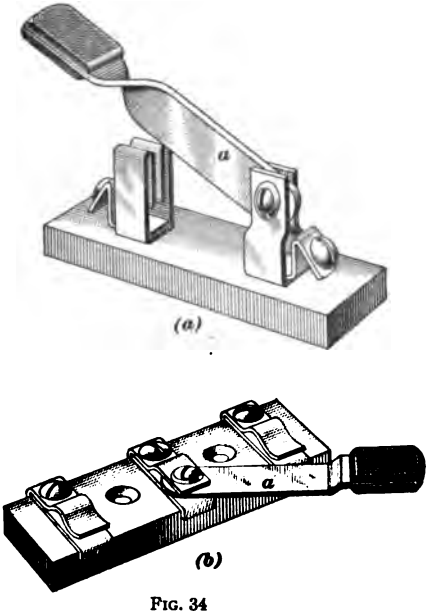


FIG. 34

83. Wiring the Engine.—In wiring a battery system, the battery should be placed so that it will not get wet from bilge water, rain, or spray. A waterproof box is perhaps the best protection for dry batteries. The coils should also be placed in a dry position, high up on the side of the boat where

they will be protected from the weather. The switch is placed in the most convenient position for the operator.

High-tension and low-tension wires can be distinguished by the thickness of their insulation. The high-tension wire, or cable, must contain very thick insulation in order to prevent the leakage of the current of high voltage that passes through it, while the low-tension wires need not be insulated so heavily. From an electrical standpoint, the high-tension cable does not need nearly so much copper as the low-tension one, but is made heavy enough to give it strength to meet mechanical requirements.

FIG. 35

84. The switches used in motor-boat ignition systems are of various types. In some systems, knife switches like those in Fig. 34 are used. In the single-throw switch (*a*), current simply passes from one terminal to the other through the blade *a* when the switch is closed. In the side-acting, double-throw type (*b*), either end terminal may be electrically connected to the middle one by the blade *a*.

Another common type of switch is shown in Fig. 35. The blade *a* is fitted to an insulated base *b* and connection may be made through the blade from the terminal *c* to either of the terminals *d* or *e*. When the blade is in the position shown, the switch is in the off position.

BEARINGS AND LUBRICATION

BEARINGS

85. Definitions.—When it is the regular duty of a machine part to rotate, as when an axle or a shaft turns, it must be restrained or held at a definite place by a suitable support. A portion of the rotating part is in direct contact with the support that holds it and to which it fits. This

contact portion of the rotating part is called the **journal**, and the part that surrounds and carries the journal is called the **bearing.**

When a bearing is made separate and consists of one piece, it is called a **bushing**, or **sleeve.**

Two general types of bearings are ordinarily used in marine-engine practice, namely, **plain bearings**, and **ball bearings.** A plain bearing consists simply of a bearing, or sleeve, in which the journal fits and touches the surface along its entire length. A ball bearing is one in which a number of balls surround the journal and lie between it and the bearing proper. Each ball thus touches the journal and the bearing surface in single points, instead of along lines. The frictional resistance is much less than in ordinary bearings.

A **thrust bearing**, which may be either a plain bearing or a ball bearing, is a bearing used to prevent end thrust, or motion, of a shaft.

86. Metals for Bearings. Journals are commonly made of either iron or steel, while bearings are generally made of a softer metal. This is done for a two-fold purpose. In the first place, there is less friction between a journal of hard metal and a soft-metal bearing than between two hard metals. In the second place, it is cheaper to repair or replace a worn bearing than a worn journal. The principal metals used are brass or bronze and Babbitt metal. Brass is an alloy of copper and zinc; it varies in color from a bright yellow to a dark copper color. Some brasses are quite soft, while others are too hard for use as bearings. Bronze is an alloy of copper and tin, though lead is also added, at times.

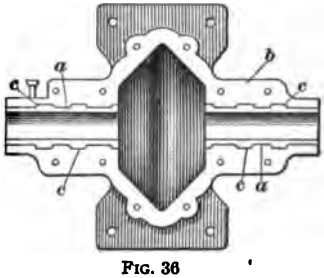


FIG. 36

87. Plain Bearings.—Crank-shaft bearings and connecting-rod bearings on marine engines are of the plain type. One form of crank-shaft bearing is illustrated in Fig. 36, which is a top view of the lower half of the crank-case of the Fairbanks-Morse, two-cycle engine. The bearings consist simply of the

Babbitt metal *a* supported by the crank-case *b*. Irregularities *c* in the bearings prevent the Babbitt from moving endwise. This form of bearing with various modifications is used on a large number of engines.

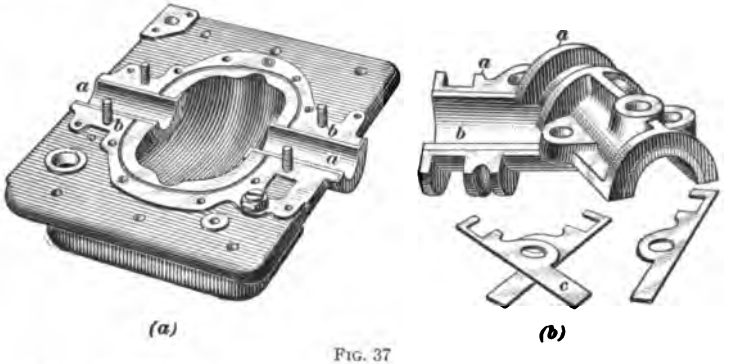


FIG. 37

88. Another form of plain crank-shaft bearing is shown in Fig. 37 (*a*) and (*b*). View (*a*) is the lower half of the crank-case containing the lower part of the bearings and consists simply of the Babbitt metal *a*, which is flanged at the ends to prevent endwise motion. The upper half of the bearing, view (*b*), consists of bronze castings *a* lined with nickel Babbitt *b*. The bearings may be adjusted for wear by placing

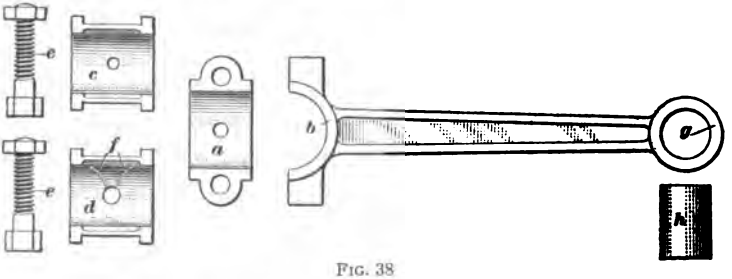


FIG. 38

shims c between the two halves of the bearings and then removing one or more when necessary to secure a proper fit around the crank-shaft. The upper half is bolted to the crank-case by means of the bolts shown at *b*, view (*a*).

89. Connecting-Rod Bearing.—A typical connecting-rod bearing is shown in Fig. 38. It consists simply of the bronze boxes *a* and *b*, which are lined with the Babbitt liners *c* and *d*. The lower box *a* is held in position by the bolts *e*. The liners contain oil grooves *f* by which oil is distributed over the bearing surface. The piston-pin end *g* of the connecting-rod is provided with a bushing *h*. Sometimes the lower half of the bearing is hinged to the upper half, in which case only one bolt is necessary; in other cases, as in heavy-duty engines, four bolts are used.

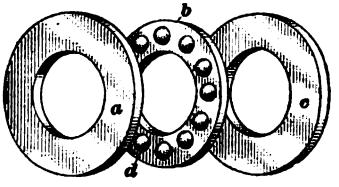


FIG. 39

90. Ball-Thrust Bearings.—Ball-thrust bearings are used in marine engine practice to prevent the thrust, or pressure, of the propeller from causing excessive pressure. A simple thrust bearing is seen in Fig. 39. It consists of three rings *a*, *b*, and *c*, of which the middle one contains a number of balls *d* placed at regular intervals in holes in the ring. One of the rings *a* and *c* is placed on each side of the balls. Pressure on the two outer rings is taken by the balls and rolling, instead of sliding, friction results. Other ball-thrust bearings employ different methods for holding the balls in place, but the principle of all such bearings must necessarily be the same.

91. Stern Bearings.—In marine practice, the stern bearing of the propeller shaft is usually fastened to the stern post of the boat. Stern bearings are ordinarily made of bronze and are of various shapes and designs. A type of plain bronze stern bearing is shown in Fig. 40. These bearings may be lined with Babbitt, or with a bar of tough wood known as *lignum vitæ*.

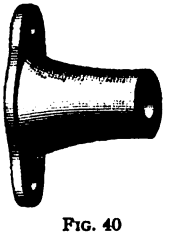


FIG. 40

Stuffingboxes inside the stern bearing are used to prevent water from leaking into the hulls of boats around the propeller shafts. In smaller boats, they may be used in place of stern bearings, and are frequently placed on the outside.

92. Struts.—Where the end of a propeller shaft extends to quite a distance beyond the hull of the boat, an outer bearing is necessary; this is termed a **strut.** It is usually made of bronze with a Babbitt lining, and is fastened to the hull by means of two rather wide flanges. After the bearing is fastened it is babbitted with the shaft in place, with a thin piece of paper around the shaft to permit some clearance, thus making allowance for possible swelling or shrinking of the wood.

LUBRICATION

93. Methods of Lubrication.—Lubrication consists in introducing some substance, either liquid or solid, between two rubbing surfaces, to reduce the friction and the wear that otherwise would occur. No matter how smooth a metallic surface may appear to the sight or to the touch, it is, in reality, covered with very minute projections, or ridges and hollows. These are readily seen under a microscope. Hence, when two clean metallic surfaces are placed together and motion is imparted to one or both of them, so as to cause one to slide or roll upon the other, these little ridges engage one another, or interlock, with the result that some of the projections are torn loose from each piece. It is this tearing away or abrading of the metal that causes wear, and the resistance thus offered is known as *friction.*

When a lubricating substance, such as oil, grease, or graphite, is put between the two surfaces, it fills the little hollows and forms a thin film or layer that prevents the metals from actually touching each other except at the highest points. As a result there is less wear, since a smaller number of ridges are torn loose, and this means less friction also.

94. The principal parts of a gasoline engine to be lubricated are the cylinder, the piston-pin bearing, the lower connecting-rod bearing, and the main crank-shaft bearings. Oil is supplied to these bearing surfaces in several ways, which may be classified as follows: *gravity feed, splash lubrication, pressure feed, force feed, circulating system,* and *lubrication through the fuel.*

95. Gravity System.—The simplest system of lubrication for the marine gasoline engine is the *gravity system*, by means of which oil is delivered to the bearing surfaces through common gravity sight-feed oil cups. This system finds its most extensive application on small single- or double-cylinder engines. The gravity method of lubrication is illustrated in Fig. 41, which shows this system applied to a single-cylinder two-cycle

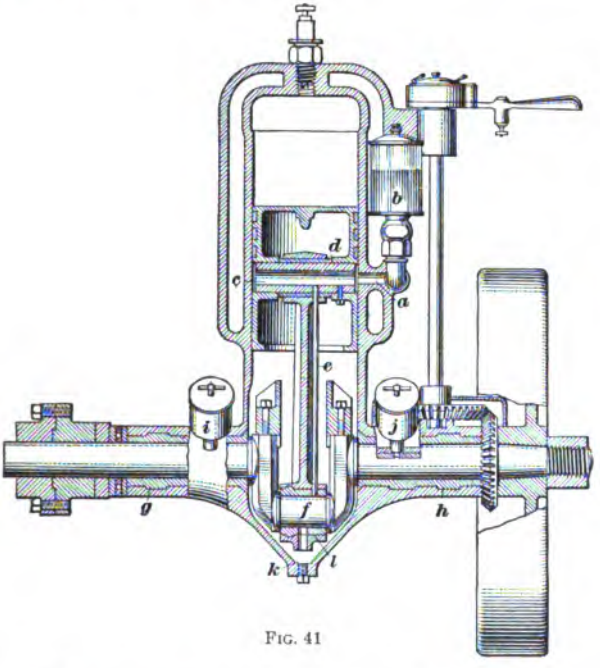


FIG. 41

engine. The oil is supplied to the cylinder through the passage *a* from the oil cup *b*. Some of the oil from this cup is conducted by the hollow piston-pin *c* through an opening to the upper connecting-rod bearing *d*, while a portion of it flows through the tube *e* to the lower connecting-rod bearing *f*. The main crank-shaft bearings *g* and *h* are lubricated by the cups *i* and *j*, respectively. Any surplus oil falls to the bottom of the crank-case *k*, from where it is thrown about, further lubricating the moving parts, by the scoop *l* on the bottom of the connecting-rod.

96. Splash Lubrication.—In some engines, the crank-case is completely closed, and a quantity of lubricating oil is poured into the lower part of the case. At each revolution of the crank the end of the connecting-rod dips into the oil, splashing it about and thus lubricating the cylinder and bearings of the engine. This method of lubrication is termed the

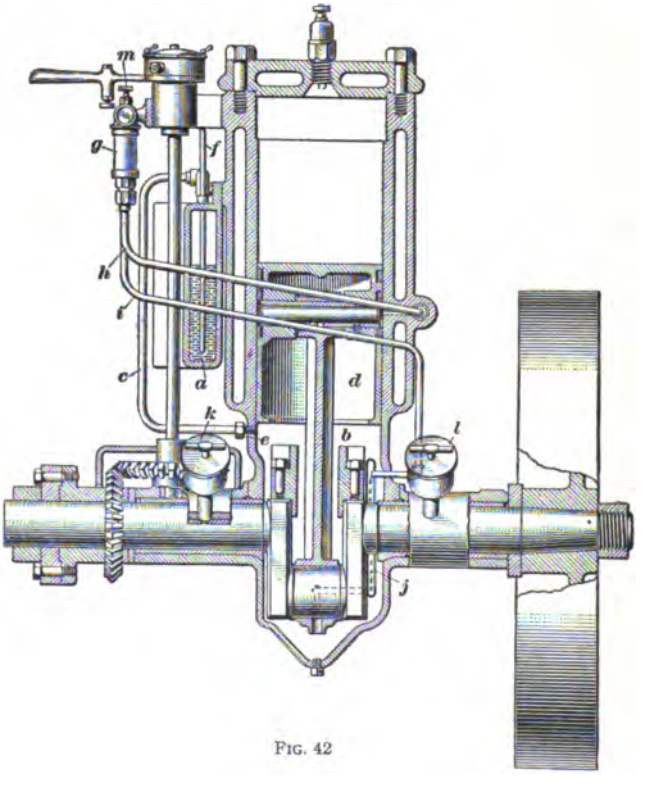


FIG. 42

splash system. The splash system of lubrication has the disadvantage that the amount of oil thrown depends largely on the speed of the engine, and also on the degree of care exercised to keep a constant oil level in the crank-case. Although this system of lubrication has been found exceedingly satisfactory as regards the main shaft, crankpins, etc., the sensitiveness of the cylinders to overlubrication or under-

lubrication has caused most makers and users to prefer separate cylinder lubrication. This system cannot be satisfactorily used in the two-cycle type of engine because too much oil would be carried through the by-pass into the combustion chamber.

97. Pressure-Feed Lubrication.—In the pressure-feed lubricating system, the oil is forced from a reservoir to the various points to be lubricated by pressure obtained from the crank-case. The oil reservoir is connected to the crank-case by means of a pipe; hence, on each downward stroke of the piston, the oil is forced through the system by the pressure from the crank-case compression. A typical pressure-feed lubricating system applied to a two-cycle engine is shown in Fig. 42. The oil reservoir *a* is connected to the crank-case *b* by the pipe *c* and on each downward stroke of the piston *d*, the oil is compressed in the reservoir. The pipe *c* contains a check-valve *e* that maintains the pressure in the reservoir. A pipe *f* leads from the reservoir to the sight feeds *g*, and two pipes *h* and *i* lead from the sight feeds to the cylinder and the crank-case, respectively. When the oil is compressed in the reservoir, it flows through *f* to the sight feeds, thence to the cylinder and upper connecting-rod bearing by way of the pipe *h* and to the lower connecting-rod bearing by way of the pipe *i* and the ring *j*. The main crank-shaft bearings are lubricated by means of the sight-feed oilers *k* and *l*. The sight feeds *g* allow the operator to see exactly the rate of flow of the oil to the bearings. This rate can be adjusted by means of thumb-nuts *m*. There is a separate sight feed for each bearing to which oil is fed from the reservoir.

98. Force-Feed Lubrication.—In the force-feed lubricating system oil is forced to each bearing by means of a mechanical oiler, or force-feed pump. The oiler is positively driven, usually by gears, from the engine crank-shaft and pumps oil from the crank-case to the various bearings. Each bearing is provided with a separate tube leading from the oiler, and the pressure is sufficient to keep the tubes open. An advantage of this system is that the oiler stops and starts with the engine and, therefore, needs no attention when the engine has been brought

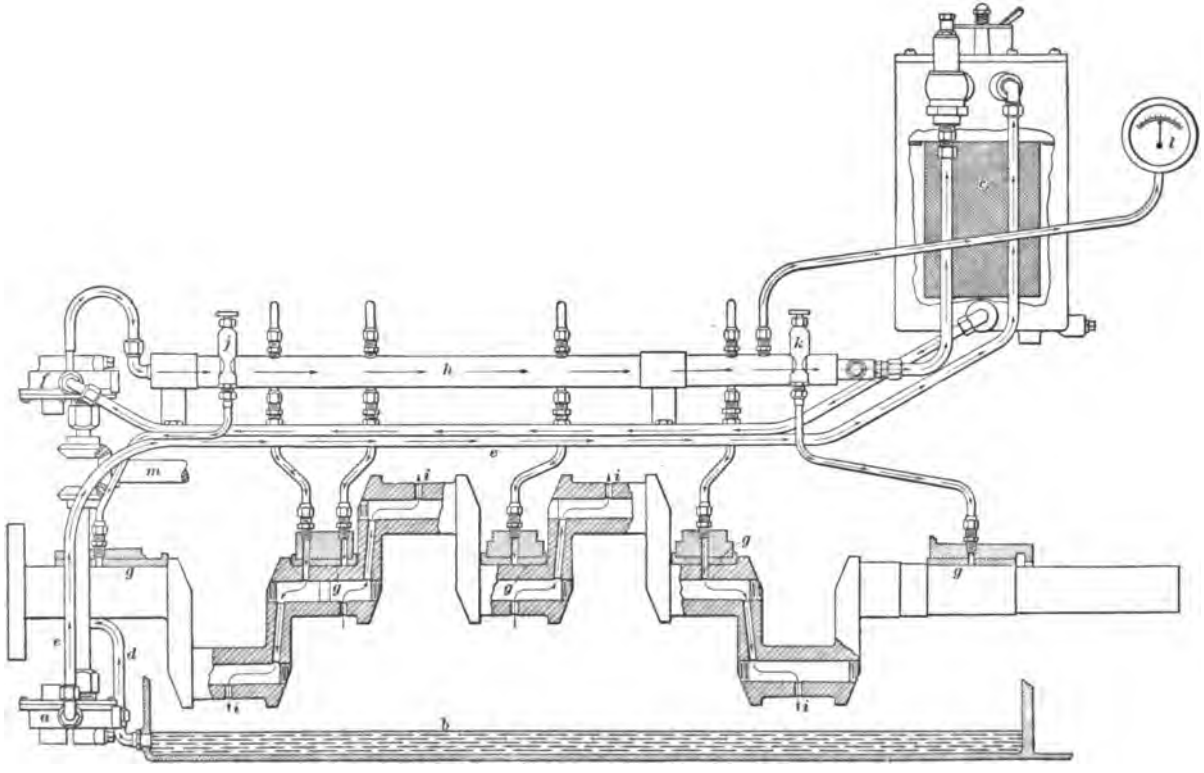


FIG. 43

to a standstill. Each oil tube may be individually regulated so that just the exact amount of oil necessary is fed.

99. Circulating System.—In the circulating system of lubrication, the oil is pumped to the various bearings from a reservoir that is fed from the crank-case, and then it is allowed to flow back to the crank-case and used again. This system is economical in operation and has the advantage of delivering oil to the bearings under pressure, but it is not suitable for use in two-cycle engines on account of the crank-case being used for precompressing the fresh charge.

A typical circulating system is shown in Fig. 43, which shows the piping to the crank-shaft bearings of a four-cycle four-cylinder engine. By means of a gear-pump *a* oil is pumped from the crank-case *b* to the reservoir *c* by way of the pipes *d* and *e* as shown by the arrows. A second gear pump *f* takes the oil from the reservoir *c* and forces it through the main crank-shaft bearings *g* by way of the pipe *h*. From the main crank-shaft bearings the oil flows through the hollow crank-shaft to the connecting-rod bearings *i*, from which it drops to the crank-case. By this system the same oil is circulated through the reservoir and bearings a great many times. Sight feeds *j* and *k* are provided for the purpose of showing the amount of oil flowing into the end crank-shaft bearings. The pressure of the oil flowing through the system is registered by means of the pressure gauge *l*. The pumps *a* and *f* are driven from the cam-shaft *m* by means of two vertical shafts and bevel gears. The cylinders and upper connecting-rod bearings are lubricated by the ends of the connecting-rods dipping into the oil in the crank-case and splashing it up into the cylinders.

100. Lubrication Through the Fuel.—A common method of lubricating the moving parts of a two-cycle gasoline marine engine is by mixing the oil with the fuel in the gasoline tank. The oil is drawn into the crank-case and engine cylinder with the gasoline vapor and carried to the various bearings. An advantage of this system is that the engine is unencumbered by any kind of lubricating apparatus, and the lubrication is entirely automatic when the oil is once put into the

fuel tank. The proportion of oil to gasoline ordinarily used is about one pint of oil to five gallons of gasoline for a new engine, and about one pint of oil to eight gallons of gasoline for an engine that has been run for some time. It is not possible to use this system of lubrication with a four-cycle engine because such an engine takes its full charge directly into the combustion chamber and the oil would not get to the crank-case and crank-shaft bearings.

101. In order to secure good results with any method of lubrication, it is necessary to make use of the best grade of gas engine oil obtainable. On account of the excessive heat to which a gasoline engine cylinder is subjected, only a good grade of *mineral oil* should be employed for lubrication purposes. Heavier oil may be used in summer than in winter because oil will flow more freely in warm weather than in cold. It is the best plan to follow the directions of the manufacturer of an engine concerning its lubrication and to purchase the grade and make of oil recommended by him.

MANAGEMENT OF MARINE GASOLINE ENGINES

(PART 1)

MARINE-ENGINE INSTALLATION

SELECTING AN ENGINE

WEIGHT OF ENGINES

1. Before buying a boat one is generally familiar with the conditions of the water in which it is to operate and chooses a boat accordingly. Different types of craft are required for the open sea, bays, sounds, lakes, and rivers and these types are again divided into special forms suitable to the uses for which they are intended. These divisions, in turn, require that an engine be selected that will perform the work necessary for the type of boat and the conditions encountered. In the open sea, a boat is frequently subjected to heavy poundings and long swinging strains, the propeller at times racing in the open air and the flywheel having its angle of motion suddenly shifted by the pitching and rolling of the boat. Sudden variations of load and strain accompanying these conditions can be endured by a lightly built engine only a short time. Also, the higher the number of revolutions the greater is the liability of breakdown. Therefore, the engine selected for work in waters where heavy seas prevail must be substantially built and have a comparatively small number of revolutions per minute.

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The opposite type of boat is represented by the hydroplane which is intended for smooth water only; the engine is therefore light, with high speed. The speed of engines for boats to run in the open sea vary from about 325 to 600 revolutions per minute, with the preference for engines revolving not more than 450 times per minute. For the hydroplane, the number of revolutions per minute varies from 800 to 1,500 and the speed is correspondingly high.

2. Weights of Engines.—The weights of the engines vary from $2\frac{3}{4}$ pounds per horsepower to over 100 pounds per horsepower. Between the extremes there is the semilight-weight, high-speed engine of from 10 to 20 pounds per horsepower and 800 to 1,000 revolutions per minute. They are for use in lightly built runabout craft with speed varying from 12 to 20 odd miles an hour. With them, but in another division, is the engine favored by the great majority. It weighs from 40 to 70 pounds per horsepower and turns from 350 to 500 revolutions per minute. The earlier engines of this weight were equipped with make-and-break ignition on account of the seeming impossibility of keeping the high tension of a jump-spark ignition system from leaping all over the boat whenever the slightest spray was flying. Now, with the combined coil and spark plug, this is changed and the jump spark is usually to be preferred.

If the engine is to be put into a speed boat it must be light; but if the boat is intended for cruising, or general use, the engine may have some weight. The heavier the engine the more hard usage it will stand. A boat for general use usually requires ballast and it is as good in the form of an engine as in any other.

There are a number of makers of all the different types of engines whose product is perfectly reliable, but as a rule it is safe to purchase from any maker whose product has been on the market for many seasons, giving, for the sake of convenience, the preference to one within reach of home.

3. Choice of Propeller.—The propeller should be selected for the kind of work in which it is to be used. Heavy work calls for a heavy propeller. It is of little use to put a

two-bladed racing propeller on the same shaft with a heavy-duty slow-running engine, or to combine a heavy three-bladed broad wheel with a high-speed engine. The three-bladed broad wheel should be used for outside and general work, and the two-bladed, narrow, knifelike propeller for speed work.

POWER OF ENGINE

4. The designer of a motor boat always has a fairly accurate idea of the power necessary to drive it at certain speeds, and it is safe to use what he suggests. It is more than likely that he has designed similar models before and knows from experience the speed at which they are driven by the power installed, because every hull has a speed at which it drives most efficiently. In the ordinary 20-foot boat, a power plant of 4 or 6 horsepower is all that can be economically used. As the normal speed may be 7 miles an hour 5 horsepower will be likely to give her that speed. By installing a 10-horsepower engine, the gain in speed will be about 1 mile an hour, and more than likely the power cannot all be used because of the extravagant settling by the stern; this settling makes the boat easily boarded by seas in rough weather or turbulent waters. On the other hand, for a boat between 35 and 40 feet that is intended for outside work, and therefore is seaworthy, it is useless to install less than 25 horsepower. With that power and a fairly good model she will make from $8\frac{1}{2}$ to 9 nautical miles an hour. If in the same boat the horsepower of the engine was doubled the result will be a gain of about 1 mile an hour.

5. Power Test for Boat.—The one infallible test whereby it can be known whether a model can stand more power economically is whether or not at her present speed the boat raises a large bow and stern wave, or, whether she slips along with very little disturbance of the water. More power can be given until the bow wave or the stern wave is of fair size compared to the size of the boat. This wave is noticeable even to the untrained eye though its meaning is not known to the inexperienced man. When that wave forms, the addition of more power makes the

boat push water like a towboat, or makes it try to drag heavily astern.

6. Advantages of Two- and Four-Cycle Engines. The merits of the two- and the four-cycle engines are not so far apart as they were a few years ago. The chief advantage possessed by the four-cycle engine was in the saving of fuel. At the time the marked saving was taking place the two-cycle engines were mostly using vaporizers and the four-cycle engines were using carbureters. The claim made for the four-cycle was a saving of $\frac{1}{4}$ pint of gasoline per horsepower per hour. The two-cycle engines are now mostly using the carbureter and the difference in fuel consumption is lessened. The three-port, two-cycle engine has accomplished a further saving. At the present time the difference is so slight that it is not to be taken into account. There was also a difference in the smoothness of running but with the advent of the multicylinder, two-cycle engine that also does not carry the weight accorded it previously.

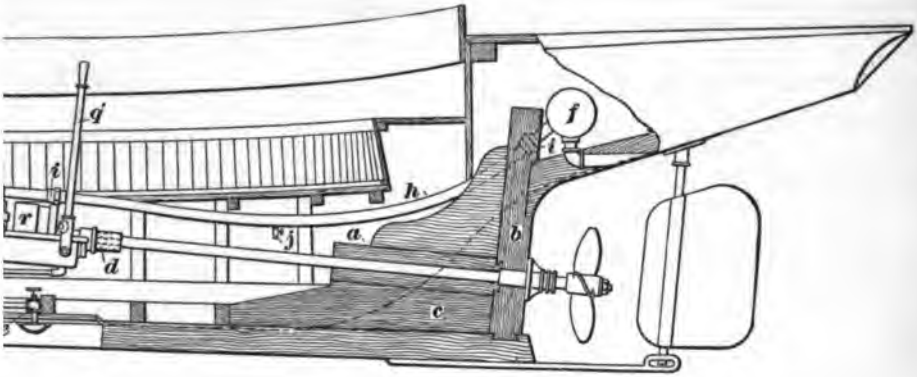
In favor of the two-cycle engine can be stated the fact that it is easier to care for and to handle. With most two-cycle engines, a reverse gear is not an absolute necessity, neither are there valves to be ground in and adjusted. The simplicity of the two-cycle engine and consequent ease of operation cannot be attained by the four-cycle.

For fineness of operation the argument is probably yet in favor of the four-cycle. For the all-round use of the man who must be his own engineer, and has not much time to devote to it, the two-cycle engine is unquestionably the best.

INSTALLATION OF ENGINE AND AUXILIARIES

LOCATION OF PARTS

7. A common method of arranging the engine and accessory apparatus in a boat is indicated in the installation diagram shown in Fig. 1. While this is by no means the only arrangement, it will illustrate the relative location of the various parts.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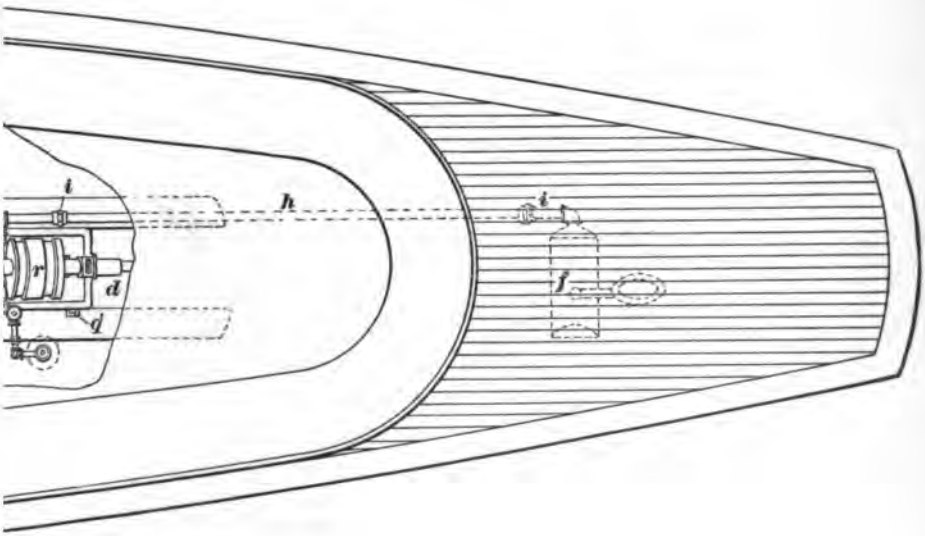
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The parts shown in the diagram are: the shaft log *a*, stern post *b*, dead wood *c*, compression coupling *d*, sea cock *e*, muffler *f*, gasoline-supply tank *g*, engine exhaust pipe *h* leading from the engine to the muffler *f* and connected up by means of two unions *i*, and an elbow, a petcock *j* at lowest point in pipe, battery *k* and spark coil *l*, view (*b*), outboard gasoline-supply pipe *m*, view (*a*), from supply tank *g* to carbureter *n*, view (*b*), reverse rod *o* for forward, or bow, control, consisting of a galvanized-iron pipe with ends shaped for connection to reverse-gear mechanism and to lower end of reverse lever, which is held in the bracket *p*, regular reverse lever *q* in bow of boat, which can be removed from its usual position *q'* on gear-case *r*, air pipe *s* leading to whistle tank *t* to which the signal whistle is attached, brass strainer *u* on outlet pipe in gasoline tank, hand wheel *v* for operating valve in gasoline-supply pipe, and brass tank plate *w* provided with two small vent holes.

8. To install a marine gasoline engine so as to insure maximum safety and freedom from excessive vibration necessitates a thorough understanding of all the requirements to be met, including the construction and location of the fuel tanks, engine, carbureter, piping, etc., and also a thorough knowledge of the operation of the engine. Before any attempt is made to install the engine, there should be provided a working blueprint or drawing, indicating the distance from the center line of the crank-shaft of the engine to the under side of the bed or lugs, giving all the dimensions and showing plainly the outline of the base below the bearing side of the lugs. A drawing of the longitudinal and athwartship, or crosswise, pieces, with the dimensions plainly marked, should accompany the drawing of the engine base.

INSTALLING THE ENGINE

9. Location of Engine.—For light speed boats, the practice is to install the motor aft of the center of the boat that it may help lift the bow out of the water when running. This lifting, or *planing*, reduces the skin friction, which is one of the principal hindrances to speed.

The location of the engine is a matter which is largely governed by the purpose for which the boat is intended. No hard-and-fast rule can be given. In general it should be placed so that its weight will not seriously affect the normal trim of the boat. Placing the motor in the center of the boat helps to give a long propeller shaft and consequently less pitch to the engine. It also makes a handy arrangement for the tanks. By placing a tank on either side, the fuel feed is equalized no matter how the boat may roll.

10. The objection to placing the engine in the cabin is that in summer it creates heat while in all weathers it creates smell. The cabin is meant for comfort, but with the engine in it the occupants get little. Most of the room is taken up by it and the room not thus occupied is taken up with the tools. In bad weather, the floor space not usurped by the tools is covered with oil, which is tracked all over the boat and moving about becomes dangerous in both cabin and cockpit. The engine should have a room by itself or be put aft of the cabin and housed. A very good compromise is to put it so close to the rear of the cabin that by the use of slides, or sections in the rear cabin wall, the engine may be gotten at handily. At night, or when the boat is not running the sections are replaced and the smell excluded.

11. Construction of Engine Bed.—The bed for the engine should be of sufficient width and length. The more the bottom is covered by the engine bed and the more the bed is made a part of the interior strength of the boat, the less will be the vibration of the hull, and the greater the power that will be delivered to the propeller. The bed for a 20 horsepower engine should be at least 8 or 10 feet long. On the sides, it should spread to the first bilge stringers, and should be notched and bolted to all the frames. The racking caused by vibration will be lessened if the bed is made even longer than 8 or 10 feet. The side thrust of engines is not reckoned with to any great extent in boats in general. The power of the engine and the life of the boat timbers are increased by using a wide bed. For instance, an open canoe, with a two-cylinder, 5-horsepower

motor set on a bed 14 feet long has been driven for several years in open waters and in billows several feet high without a sign of racking. She has withstood the roughest kind of weather in runs hundreds of miles long.

12. One form of engine bed is shown in Fig. 2. First the cross-members *a*, which should be of sufficient size, are fastened across the boat at about a distance of 12 inches from center to center. These pieces are fastened to the frames of the boat and lag-screwed or bolted to the keel *b*. They should be as wide from side to side as circumstances will permit and if possible should extend to the round of the bilge. The fore-and-aft timbers *c* are notched and lag-screwed or bolted to the athwartship pieces *a* as shown. If bolted, the fitting must be done before the crosspieces are laid

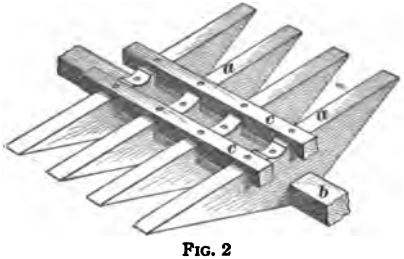

FIG. 2

13. Lining Up the Shaft.—When laying the engine bed, the first thing to do is to line up for the shaft. With the engine will usually be given the height the center of the flywheel should be placed above the bottom of the boat. If no height has been given, the distance from the center to the rim of the flywheel should be measured and 3 or 4 inches added for clearance from the bottom of the boat. An upright should be nailed to the bottom at the point where the face of the flywheel will come; this should be cut off at the height of the center of the wheel. The object of the clearance is to prevent the wheel, when revolving, from throwing about bilge water that may be in the bottom of the boat. The objection to too much clearance is that it is liable to give the engine too great a pitch. The engine should be as nearly level as possible, and in any case the pitch must not exceed 3 inches to the foot.

After the upright has been cut off, a nail should be driven into it in the exact center of the width of the boat. A string should next be passed through the hole in the shaft log and a

stick tied to its outside end. The string should be pulled taut and its inside end fastened to the nail, close down; the stick drawn flat against the hole on the outside is then shifted until the string passes through the exact center of the hole. The top of the engine bed should be from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch lower than the engine is to be placed, and must run parallel to the string that passes through the shaft-log hole. The distance between the top of the bed and the string should be made equal to the distance between the under side of the engine and the center of the shaft plus $\frac{3}{8}$ inch.

14. Placing Engine on Its Bed.—The engine is next placed on the bed and the shaft run through the shaft-log boring and propped in position. The engine is then lined up with the shaft and wedges placed under the four corners to force it into position. The wedges should be of hard wood, about 6 inches or 10 inches long and tapered from $\frac{3}{4}$ inch to nothing. After the engine has been bolted to the bed, the shaft may be slipped in place and fastened. When nails or bolts are to be driven through the wedges, holes should be bored to prevent their splitting.

When placing the stuffingbox on the dead wood, care should be taken that it lies at perfect right angles with the shaft. If it does not, the dead wood must be cut into until the stuffingbox is at right angles with the shaft, or else, when the box nut is screwed home it will bind on the shaft. To know if all is well here the engine should be turned by hand with the petcocks open. With cylinders and bearings well-oiled, the engine should now crank easy.

INSTALLATION OF AUXILIARIES

15. Propeller Shaft.—To be efficient, the size of the propeller shaft should be in proportion to the power it is to carry. The spacing of its supports must not be too far apart or it will have a tendency to wobble. Its bearings should be broad for the purpose of giving it steadiness and long life, especially should its bearing through the flywheel be the same or they will require frequent adjustment. If much of the shaft projects

through the boat without the support of struts the propeller will wabble and send heavy vibrations through the hull; this will bring about the rapid destruction of the stuffingbox.

Stuffingbox troubles may be remedied to a large extent by equipping the shaft with an inside stuffingbox. Where there is no inside stuffingbox, the influx of water that takes place overnight at times can be done away with by erecting a small bulkhead arcoss the boat just forward of where the shaft enters the bottom. The bulkhead can be made of 1-inch boards to reach to a height of 2 or more inches above the water-line. A hole may be bored through it for the shaft. The board need not be fitted exactly to the bottom of the boat, but along its after edge where it joins the bottom, the space can be filled with rubberoid roofing, and a strip of pliant wood fastened along the joining to hold the rubberoid in place. This strip should be fastened and drawn tight with brass screws. The shaft can be fitted with a collar at the hole, some wicking smeared with graphite wound around it, and the collar screwed down as snug as is required. By this arrangement, any leak from the outside stuffingbox will not fill the boat, and the water from such a leak will rise only to the height of that on the outside. The weight will be so little that the trim will not be affected.

A straight line can be secured for the propeller shaft by using a universal joint between it and the engine. However, for rough-water work this is a weak construction. An advantage of the universal joint is that with it a shaft can be used that can be raised and lowered in shallow water, reeds, and the like. The raising and lowering is done through a slot, or well, that is built into the boat and is a great convenience in some localities. What is known as the *funnel stern* answers practically the same purpose.

16. Propeller.—The propeller should be placed as close to the stern of the boat as is safe. By this is meant that enough clearance must be provided so that a bent blade will not hit and cut the stern. When a blade is slightly bent, it can be hammered back into place by laying it on a block of wood and having

another piece of wood between the blade and the hammer. If much bent it should be sent to the maker who will put it back into form. A blade that has been badly bent is liable to break off at any time when in use. The top of blades should be submerged 2 or more inches under the surface to get a strong hold on the water.

If the propeller turns in the direction of the hands of a clock when standing back of the stern and looking at it, the twist of the wheel in the water will tend to push the stern of the boat to the right, or starboard. If the propeller turns in the opposite direction, the push of the stern will be the opposite. The reason for this is that the water below is more solid than that at the surface, and offers greater resistance to the thrust of the blade. Because of this a boat turns in a smaller circle one way than the other.

Propellers will sometimes jar loose. They should be keyed on and a setscrew used, or a cotter pin placed through the end of the shaft.

17. Salt-Water Fittings.—Special fittings are required for use in salt water because bronze or brass near iron or steel in salt water set up a galvanic action that will quickly eat away the iron. If a bronze propeller is placed on an iron shaft this action will quickly eat away the shaft and cause the propeller to be lost. In one instance an iron setscrew on a bronze shaft was eaten away on a 100-mile run. Iron pipes for the water circulation will soon choke with rust and will fill the water-circulation passages in the water-jacket with rust. The bolts through the ground-joint pipes in the water circulation on either side of the water-jackets should be of brass or bronze. Iron bolts will readily corrode. There should be no iron or steel struts near any bronze or brass fittings. Stuffingbox and bolts should be of bronze, and also the shaft log if it is made of metal. There should be nothing whatever in the water circulation that is made of anything but brass or bronze. The interior of the water-jacket and the exterior of the cylinders are of such large construction that the corroding action is slow within them, but they should be cleaned out once a year.

Nothing about the pump should be of any other material but brass or bronze.

18. Exhaust Pipe.—The larger an exhaust pipe is, the better the engine will work and the more power it will develop. There should be but few bends in it and these should be at as large an angle as possible. Every 45° angle gives a resistance equal to the friction of 15 feet of pipe. The passage of water through the exhaust pipe reduces the speed of the boat some, but it is necessary for the purpose of keeping the pipe cool. The exhaust should not pass near a fuel tank even though the pipe is covered with asbestos. Accidents to the covering of the pipe may occur and consequently there is danger of fire or an explosion.

19. Mufflers and Under-Water Exhausts.—When a muffler is used, the power of the engine is reduced to a slight extent due to the back pressure produced by the additional friction of the muffler. On account of this, it is a good plan to have the engine fitted with a muffler cut-out, or two-way exhaust, by means of which the engine may exhaust into the open air when occasion permits. The boat may be started more readily by this means and when running in localities where the laws permit it, the muffler may be cut out and the maximum power obtained without increasing the wear on the engine. An increase of power is obtained in speed boats by doing away with the manifold, or common exhaust pipe, and having a separate pipe for each cylinder. Where facilities are at hand to make the change, additional power can sometimes be obtained by leading the exhaust from each cylinder to one common pipe of larger dimensions, the opening to which is aft of the last cylinder.

20. The muffler to be efficient must have a larger opening leading from it than is in the pipe that conveys the exploded gas to it. The sharper the angles of the baffle plates the more resistance, and consequently, the greater the back pressure. The muffler should be thoroughly covered with asbestos, and after an explosion of gas in it, it should be examined to see that

it has not been cracked. Explosions in the muffler are usually the result of misfiring or of too rich a mixture.

Whether or not a muffler or an under-water exhaust causes an appreciable decrease in the power of an engine may be ascertained by a simple test with a common revolution counter. The motor should be started and the number of revolutions per minute taken with the exhaust open to the air, after which the speed should be taken with the silencer in use. A comparison of the number of revolutions per minute will show if there is much loss of power. If the drop in speed is not greater than 25 to 50 revolutions a minute, the silencer is considered of average efficiency.

21. In using the under-water exhaust, it is customary to have the exhaust make its exit at some point just on the water-line. Then, when the boat is under way and begins to gather speed the stern will settle and submerge the exit. Directly at the stern center is not a good position on account of the dragged water flowing directly against the stern instead of away from it. This dead water, as it is called, may be detected by dropping a piece of cotton waste on the surface of the water an inch or two from the stern and observing its action. A better place for the exhaust is on the side of the stern where a strong current is sure to carry the exhaust away instead of pushing it back.

With the exhaust under water at all times it is often hard, if not impossible, to start the motor because of the resulting back pressure. On many boats using the under-water system of muffling it can be readily demonstrated by having some people stand near the exit of a water-level exhaust, that the sinking of the exhaust several inches below the surface will materially slow down, if it does not entirely stop, the engine.

The exhaust pipe is sometimes installed at an upward angle from the muffler to the point of exit. This renders the muffler liable to become partly filled with water when a sea rises well above the opening. It is better practice to carry the pipe in an arch, or even at a slight angle, downwards to the point of exit and thus prevent the inflow of water.

GASOLINE TANKS AND PIPING

TANKS

22. For the storage of the gasoline, kerosene, or crude fuel oils, the tank required should be so constructed that it will retain the fuel under all conditions of weather. For economy of space the greater number of tanks are made to fit into the bow, the bilge (side), or the stern of the boat. These tanks present large flat surfaces at their different sides, against which the 10 to 40 gallons of fuel that they contain deals heavy blows while in a seaway. In order to prevent the fuel from rushing from end to end of the tank and also to support, or stay, the sides and bottoms, tranverse partitions, or **baffle plates,** are provided in the interior of the tanks. These should be open at the bottom to allow a free passage of the contents from one compartment to another. By the use of these plates, the force with which the fuel strikes the sides and ends of the tank is greatly reduced.

23. A tank made in cylindrical form is superior to any other on account of its greater strength and the absence of flat surfaces to be pounded. The curves of the walls turn all rushes of liquid into glancing blows. However, it is better that even this style of tank be fitted with baffle plates, both as a matter of reducing strains and of stilling the noise of the swashing that goes on in undivided tanks during a seaway.

The flat-sided tanks should have boards flattened up against them and braced to help relieve the strain, or pressure, from the inside. They should also have a raised rim around the outside of the top edges, with a small pipe leading overboard to discharge gasoline from a spill or overflow. The superiority of the seamless cylindrical tank is demonstrated if the air-pressure feed-system is used, it being a difficult matter to keep the joints of a flat-sided tank air-tight on account of the surging of the fuel against them. The round tank can be placed in any part of the boat with perfect security.

24. Tank Vents.—A vent is necessary in a tank to admit air to supply the space vacated by the fuel that has flowed to the motor; otherwise, a vacuum would be created and the flow of fuel through the pipes be suspended. The vent should be placed so that it will not admit dirt or water. Perhaps the best method of venting is by means of a curved pipe opening into the top of the tank, as shown at *a*, Fig. 3. Air, but no dirt, can enter this pipe. Another good way is to force a hole through the screw thread just below the lower edge of the filling cap. Still another method is to pierce the top center of the filling cap with a very fine hole. In this case it is better during rain, fog, or spray, to cover the cap with anything handy. The hole must be only the size of a pin.

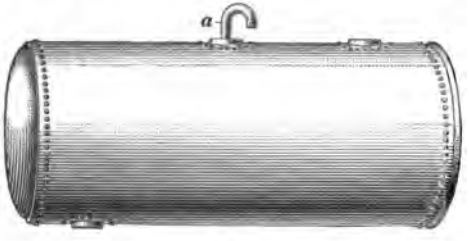

FIG. 3

25. Materials Used.—Copper is the most common metal used in making tanks because it is not corroded by gasoline or oils. Steel tanks are also often used but these should be tin-lined, otherwise the action of the water at times found in gasoline will cause the interior to rust and deposit a sediment in the fuel that will be conveyed to the pipes and carbureter.

26. Cleaning the Tanks.—All tanks should have a draw-off cock placed at the lowest point of drainage for the purpose of getting rid of the sediment that is sure to find its way into them. When it is suspected that the tank has any foreign matter in it, the valve in the pipe line should be shut off and a receptacle placed under the drainage cock. The fuel should then be let off from the tank as quickly as possible, so that it will carry with it any dirt that may be inside. Gasoline poured through the tank will clean it still further. The fuel thus flushed out of the tank can be strained through a chamois skin and regular strainer, and then poured back into the tank.

27. Care of Tanks.—All gasoline tanks should be painted on account of the corrosive action of salt water. While it is the common impression that copper will not corrode, it has been found that, if unrestrained, salt water will eat through $\frac{1}{16}$ inch of copper in two seasons.

If a leak develops, it can be plugged with common brown soap and painted with a thin coat of shellac. After this is dry, a second coat of shellac should be applied and then a piece of any kind of thin cloth that has been wet with shellac should be spread over the leak. This will make a very satisfactory temporary repair.

28. Position of Tanks.—The ideal position for tanks is to have one on either side of the boat with pipes leading from each to a main supply pipe for the carbureter. In this position, no matter how the boat is rolling, the supply to the carbureter remains constant. The bottom of the tanks should be at least 6 inches above the level of the float in the carbureter to insure a flow of gasoline to the engine. With a 6-inch elevation, the tank may be placed in any part of the boat with the assurance that even in a seaway there will be no serious results. The motor may run fitfully in a bad sea, but with either vaporizer or carbureter it will keep going if it is otherwise in good condition.

29. Air Pressure.—Sometimes it is necessary to place the gasoline tanks low down. This steadies the boat when properly placed, but it also necessitates a method of raising the fuel to the carbureter. The gasoline is usually forced to the carbureter by means of air pressure derived from a hand pump. The pump is connected to the tank by a pipe and the gasoline is thus kept under the necessary pressure. The tank and pipes in this system must of course be perfectly air-tight. Joints can be made air-tight by the use of hot sealing wax, and small leaks in the top of the tank may be taken care of by using shellac.

If air pressure is used, a small auxiliary gravity tank situated near the motor is almost a necessity. With it one is in a measure independent of the air pressure, should it fail either

by the air pipe becoming obstructed or because of leaks. In case of such an accident, the auxiliary tank can be kept supplied by drawing from the main tank by siphoning, or by inserting a small pump into the tank, or dipping from it through the cap opening.

30. Tank Indicators.—In any tank, the outlet pipe should be placed about $\frac{1}{2}$ inch above the bottom of the tank so that sediment will not flow into it. The amount of gasoline that a tank contains at any time may be ascertained by means of a measuring stick, which can easily be made for any tank. When making such a stick, fuel should first be poured into the tank until it begins to run out of the cock in the pipe line; it should then be poured in 1 gallon at a time. After pouring in each gallon, a smooth stick should be inserted to the bottom of the tank and notched where the level of each gallon of fuel comes. This stick can then be used for finding the quantity of fuel in the tank at any subsequent time. Many of the cylindrical tanks are supplied with indicators that automatically tell the quantity within. Gauges for this purpose are also made. They should not be placed in the pipe line for the reason that if anything happened to the gauge the supply of fuel would be cut off.

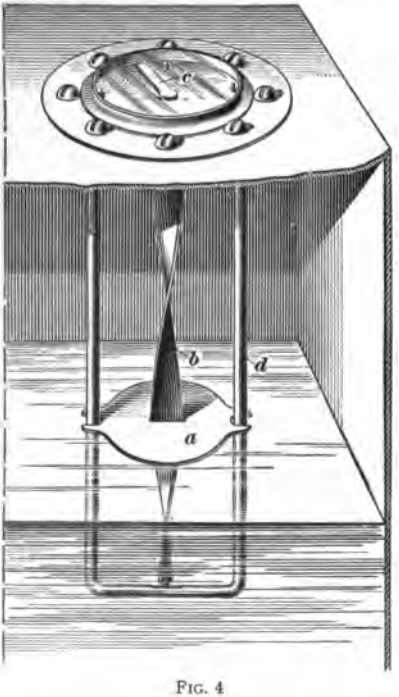

FIG. 4

31. A gasoline tank depth gauge, or indicator, for showing the depth of gasoline in the supply tank is illustrated in Fig. 4.

A float *a* rests on the top of the gasoline and rises and falls with it. A slot in the center of the float engages with a twisted flat stem *b*. As the float rises, this stem is moved around and carries with it a hand, or pointer, *c*, which moves over a dial graduated to indicate the quantity of gasoline in the tank. Rotary motion of the float *a* is prevented by the frame *d*, with which lugs at the edge of the float engage.

32. Filling a Tank.—To fill a tank with fuel, a strainer funnel should be used with a piece of chamois skin spread over it. Before removing the cap from the tank, the dust should be brushed or blown from it. The cap should be laid down bottom up, so that it will not pick up dust on its edges and thus get dirt into the fuel. If the tank is new, it should be flushed thoroughly before being filled.

The capacity of a tank should be enough to run the engine at least 20 hours. The supply can be figured for any engine from the fact that a two-cycle engine generally uses about $1\frac{1}{4}$ pints of gasoline per hour per horsepower, and a four-cycle engine, about $1\frac{1}{8}$ pints per hour per horsepower.

GASOLINE PIPE LINE

33. The pipe line should leave the tank with a spiral of two or more coils twisted into it for the purpose of taking up vibration from the motor and shocks from the waves. Coils should also be twisted into the pipe line wherever it is joined to any part that is fastened to anything stationary, the reason being that every boat buckles or vibrates more or less in a seaway and unless the pipe can give and take, it is liable to be snapped. When pipe lines are not fitted in this way, it is necessary to carry an extra length of pipe with nipples fitted on the ends for use in case of accident. If other tanks are in use the pipes from them should be brought to the main line pipe.

34. Fuel Strainers.—A fuel strainer should be set in the main pipe line for the purpose of catching any dirt or water that may be in the gasoline. The strainer should be opened

frequently, say, every eight or ten runs, to clean the fine-wire mesh. Sometimes, when oil is mixed with the gasoline in the tank, the fine mesh of the strainer gathers a gum-like substance that in time clogs enough to stop the flow of fuel. The catch of water may easily be run off by a turn of the cock at the bottom of the strainer. Frequent cleaning of the strainer will prevent the corroding of its screens. With all precaution and care the strainer will occasionaly become damaged; when it does a short piece of pipe should be inserted in the place occupied by the strainer. If the gasoline is properly strained before being poured into the tank, the probability is that the flow will continue for many trips without trouble.

35. Placing the Pipe Line.—The pipe line should not be laid where it can be trodden upon, as it may be flattened, or broken, for the finely drawn pipe is fairly brittle. If necessary to bring it across the floor it should be run in a corner or covered the same as electric wires are covered when on the outside of walls. Leaks in the line can easily be treated with shellac, the best shellac being that which has coagulated a little in the bottom of a bottle, or box.

The pipe line should be of copper, and should not be run under floors, or in out-of-the-way or inaccessible places. It should be renewed every 2 or 3 years, because it crystallizes under the constant vibration. It also may corrode in spots under the action of salt water. If it clogs, the fuel should be shut off and the pipe disconnected. It can then be blown out with an air pump, or a long wire can be run through it. It is well to have all pipes as short as possible. Ground joints in the line are more easily handled than threaded ones. Ground joints are smooth-ended and are drawn together with the use of box-like nuts.

A rubber section should never be installed in the gasoline pipe line, because gasoline is a solvent for rubber and the rubber will be carried into the piston and rings. The gasoline supply pipe should be of good size so that it will not become obstructed easily.

36. Running With Broken Pipe.—In case the gasoline pipe line becomes broken, the engine can be kept running by

pouring gasoline into the length of pipe that is attached to the carbureter. The gasoline can be poured into the pipe by using a funnel or by using the long spout of an oil can that has been cleaned out with gasoline. All that is necessary is to keep the length of pipe filled by drawing fuel from the tank and pouring it into the funnel or oil-can spout as the engine uses it.

LOCATION OF CONTROL LEVERS

CONTROL LEVERS ON ENGINE

37. In many boats, especially the smaller and less expensive ones, the levers for controlling the time of ignition and the

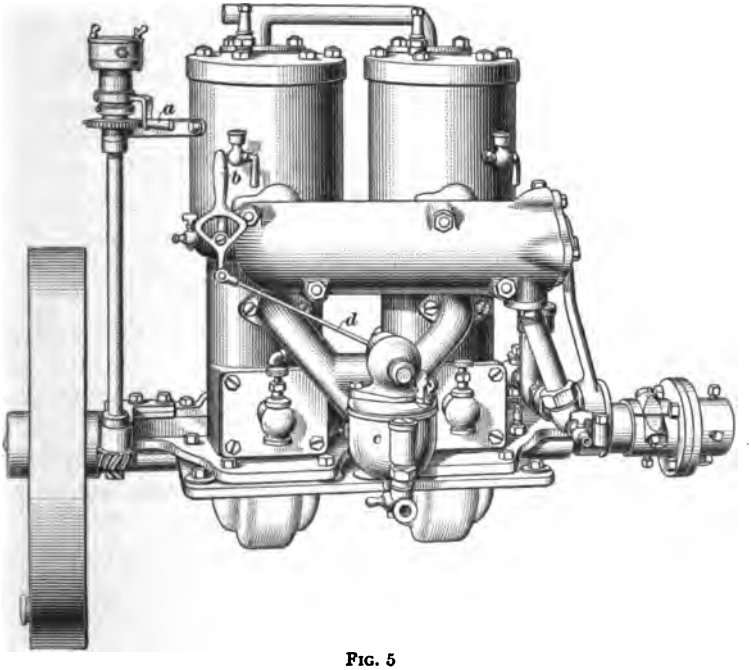

FIG. 5

throttle valve are located on some part of the engine within easy reach of the operator. In Fig. 5, the control levers are

shown located on the engine itself. The timer is operated by the lever *a*. Moving this lever in one direction advances the spark, and moving it in the opposite direction retards the spark. The direction in which to move this lever in order to secure the desired results is given for any particular engine in the instructions that are sent out by the maker. The lever *b* operates the throttle valve of the carbureter *c* through the rod *d*. The direction to move this lever in order to open or close the valve is also given in the maker's instructions.

38. The control levers are not always located in the exact positions shown but they are usually close to each other at the forward end of the engine. When one does not know the direction in which to move them, and the directions of the maker are not at hand, this information may sometimes be obtained by inspection. For instance, in order to advance the spark, it is necessary to rotate the movable part of the timer in a direction opposite to that from which the timer rotor is turning. In like manner, the spark is retarded, or made to occur later, by moving the lever in the same direction in which the rotor turns. These directions apply to timers, but in the case of magneto ignition, where the spark time is varied by moving some part of the magneto interrupter, it is more difficult to determine the direction in which to rotate the lever. One should not attempt to start an engine until he is sure that the spark is retarded; otherwise, serious injury might result.

In some makes of carbureters it is possible to tell by inspection when the throttle valve is open and when it is closed. However, by attempting to start the engine with the throttle lever in different positions, the open and closed positions may be ascertained.

It is always the best plan, especially for the novice, to follow the maker's instructions and thus clear away any doubt as to how to obtain the desired results.

BULKHEAD CONTROL

39. In a large number of boats, the throttle valve and timer are operated from levers located on the bulkhead, forming the **bulkhead control.** This form of control is made possible in the modern boat with its engine well forwards and the bulkhead between the motor and the helmsman. The switches and push buttons are fastened on the bulkhead within easy reach of the operator and are wired to the battery or magneto, or to both where a double or dual system of ignition

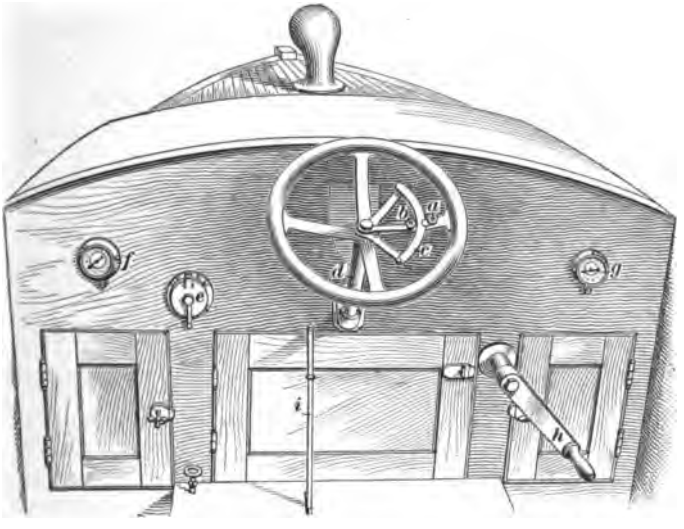

FIG. 6

is found. The levers are sometimes fastened to the bulkhead in the place most convenient to the steering wheel and a system of rods and levers lead to the timer or magneto and to the carbureter, or they may be located on top the steering wheel. With the latter arrangement, the control rods are brought up through the hollow steering-wheel shaft. Sometimes the levers are located under the steering wheel.

40. In Fig. 6 is shown a bulkhead control arrangement in which the control levers are located on the steering wheel.

The throttle lever *a* and the spark lever *b* are arranged on a quadrant *c*, around which they may be moved. They are connected to the timing device and the carbureter by means of rods passing down through the shaft *d* of the steering wheel. The switch *e* and gauges *f* and *g* are located on the bulkhead within easy reach of the steering wheel. A starting crank for the purpose of turning the engine over by hand when starting, is located at *h*, and the reversing-gear lever at *i*. This is a very convenient arrangement and one that is coming more and more into use. The bulkhead control is also sometimes employed where the engine is located aft of the cockpit, in which case the levers and rods must run aft of the steering wheel instead of forward.

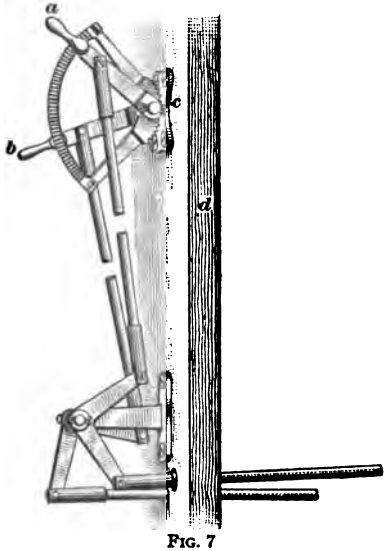

FIG. 7

41. In some cases of bulkhead control the spark and throttle levers are arranged so that they must be moved up or down in order to operate the throttle valve or the timer. Such an arrangement is shown in Fig. 7. The levers *a* and *b* are carried on the bracket *c* and are connected to the throttle valve and timer by means of the rods and bell-cranks as shown. In this construction, the rods pass from the bell-cranks, through the bulkhead *d*, directly to the devices they are meant to operate.

Another system of levers and rods is shown in Fig. 8, where the rod *a* from the lever *b* passes through the bulkhead to a bell-crank *c*. From this bell-crank a second rod *d* passes to the throttle valve or timer. In both Figs. 7 and 8 the control levers are located directly on the bulkhead and not on the steering wheel.

42. When installing the rods for a bulkhead control, the greatest care must be exercised that there is but little lost motion. Some lost motion cannot be helped but it must be small. Rods for the purpose of connecting the levers to the different parts, to be satisfactory, should be fitted with the

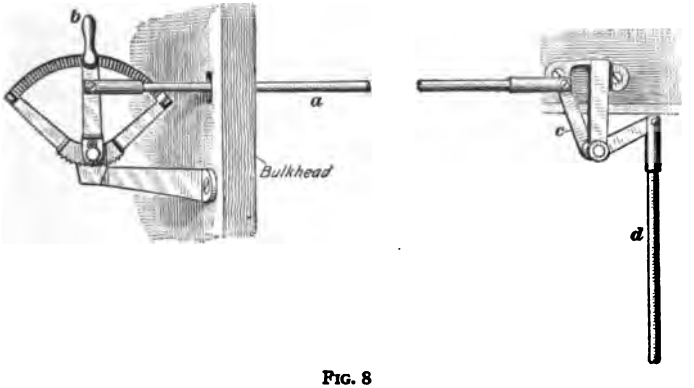

FIG. 8

ball-jointed adjustable ends. With this type of rod the length can be regulated to a nicety.

When attaching the rods to the spark, be sure at the time of connecting, that the spark is half way between full advance and full retard. In like manner the throttle should be connected when it is half way between full open and full shut.

MARINE-ENGINE OPERATION

STARTING AND STOPPING

PREPARATIONS FOR STARTING

43. When an engine is about to be started it is not safe to assume that all the adjustments are correct, just as they were when the engine left the shop, and only by careful examination can the operator be sure that the engine is ready for use. The following general rules may be applied whether the engine is of the two-cycle or the four-cycle type, either single cylinder or multicylinder:

First, determine which way the engine runs normally, whether right-handed or left-handed. When facing the flywheel and looking toward the stern of the boat, if the direction of rotation of the flywheel when the boat is going ahead is the same as that of the hands of a watch, as shown by the arrow in Fig. 9 (*a*), the engine is a right-hand engine and requires a left-hand propeller wheel to drive the boat ahead. When the movement of the flywheel is contrary to the direction of movement of the watch hands, as in (*b*), the engine is a left-hand engine and requires a right-hand propeller wheel in order to propel the boat ahead. When turning it over rotate the flywheel in its proper direction with the cocks open, or with the compression otherwise relieved.

44. Determine when the piston is on the upper dead center, and make a mark on the flywheel in case the starting pin that fits into the hole *a*, (*a*) and (*b*), is not where the mark would come. If there is no starting pin, or if it should be set at a point 90° from the upper dead center, mark the flywheel plainly to indicate when the piston is on the upper center,

another mark being made on the opposite of the flywheel to show when the piston is exactly on the lower center. If the starting pin in the flywheel is set 90° from the upper center its position should be changed to correspond with the mark made to show when the piston is on the upper center. Any other location for the starting pin is dangerous, as it may cause broken and sprained thumbs, wrists, and arms, besides other injuries.

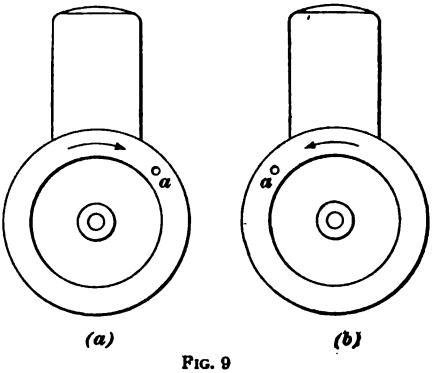

FIG. 9

45. Having marked the flywheel to show the position of the piston in the cylinder, with the gasoline turned off and the battery switch closed, turn the flywheel slowly until, if a jump spark is used, the spark coil begins to buzz, whereupon another mark should be made on the flywheel. If the make-and-break system of ignition is employed, note where contact is made and where it is broken when the spark occurs. If the engine is of a multicylinder type, try each cylinder separately, to determine whether or not the contact is made at the same relative position for all cylinders and that the spark occurs at the same point before or after the center is passed.

STARTING A GASOLINE ENGINE

46. Starting a Two-Cycle Engine.—If the engine is of the two-cycle type using jump-spark ignition or the usual form of make-and-break ignition, which will allow it to run in either direction, turn the flywheel in the opposite direction until the mark shows it to be about 30° before the upper center. Then, advance or retard the spark until a contact is made just at that point, and note the position of the spark-control lever. If the engine is of the single-cylinder, two-cycle type, the easiest method of starting the engine is to prime the combustion

chamber by injecting a few drops of gasoline into the priming cup with a squirt can, and turn on the gasoline supply in case a carbureter is used, priming it also by depressing the float; if, however, a vaporizer is used, set the needle valve at the point usually made on the dial when the engine is tested, swing the flywheel several times slowly back and forth through a space equal to about one-third the circumference, and then, taking hold of the starting pin, swing it up smartly against the compression in a direction opposite to its normal rotation, and then let go. If the engine does not start after trying this two or three times, close the valve in the gasoline supply, open the relief cock, and turn the engine over three or four times, and note whether or not explosions occur. The relief cocks should be open and the spark lever set so that ignition will occur either just after the center is passed or as near the end of the upward stroke as possible. By this test it can be determined whether or not there is trouble in the ignition system, and if there is, the trouble can be remedied.

47. A two-cycle engine may also be started by retarding the spark and turning the flywheel over against compression. By this method a good spark is obtained with the make-and-break system of ignition. When the engine has a very high compression it is often impossible to throw the wheel over. In this case the petcocks should be opened until the engine takes up its cycle of operations. Another way is to leave the petcocks on one cylinder closed until the engine is running.

Another way to start a two-cycle engine having a make-and-break system of ignition is to bring the wheel very hard up to compression in the opposite way in which it will revolve and snap the igniter trip. This produces a spark and the motor starts. If the motor is to be started in the reverse direction bring the wheel up in the opposite direction and do the same thing.

48. When starting with a jump-spark system of ignition the first thing to do after grasping the handle is to make sure that the spark is set late; then throw the wheel clear over. Another way is to bring the wheel hard up against compression

in the opposite way from that in which the wheel will revolve and then throw in the switch, the switch having been left disconnected for the purpose. Still another method is to keep the switch connected and set the timer into a very advanced position; then bring the wheel up to hard compression and throw the timer into a late spark position, sending a shower of sparks through the mixture and starting the motor. This latter method should not be trifled with unless one is very familiar with the operating of a motor. However, all these methods should be tried, without the switch connected, until a person is familiar with them. It is a great help, when starting, to have the wheel marked in such a manner that it will show exactly when each piston is at the sparking point.

49. Starting a Four-Cycle Engine.—Before starting a four-cycle engine, see that the inlet and exhaust valves, as also the spark, are correctly timed; that the adjustments are correct, that all the valves seat properly; and that they are not rusted or stuck in their guides. A drop or two of kerosene oil should be used occasionally on the valve stems. Be sure that all the oil cups are filled; that all moving parts are properly lubricated, that the sea cock is open; and that there is nothing to prevent the free passage of water through the cylinder water-jackets and thence outboard. Look out for mooring ropes that may be caught by the propeller; a few accidents from this cause will usually teach caution as nothing else will. Make sure that the electric-ignition system is in good working order by testing it with the current on, if of the make-and-break type, or by the buzzing at the spark coil if jump-spark ignition is used. Open the relief cocks or push the relief cams into position, turn on the gasoline and see that it runs freely, and turn the engine over two or three times as fast as convenient.

50. To facilitate starting, it is sometimes better to put a little gasoline into each cylinder through the priming cocks. This operation is called *priming*. After two or three revolutions, the engine should start, when the relief cocks should be closed or the relief cams thrown out, and the speed of the engine

regulated by the throttle, the proportions of the mixture being regulated by the auxiliary air valve or by the needle in the gasoline valve, unless a compensating or other form of carbureter is used.

If the engine misses explosions, it may be that it is throttled too much, but it is more probable that the mixture is too rich in gasoline vapor. If the engine begins to slow down, give it a little more gasoline, and if that does not remedy matters decrease the amount, or increase or decrease the amount of auxiliary air. When the engine is running satisfactorily, open the oil cups and see that they feed properly and that the jump operates, watching, of course, for overheated bearings, as in any new piece of machinery.

51. If the engine is directly connected to the propeller, there is nothing else to be done except to get the proportions of air and gasoline vapor as nearly right as possible; see that lubrication is constant, and that the circulating water discharges freely. If the engine has a reversing gear, there will be little need of throttling when changing from full speed ahead to a neutral position or full speed astern; but with a reversing gear and no governor, extreme care should be exercised when throwing in either gear or the engine may be stopped. The reversing gear absorbs some of the power of the engine, which is more liable to stop when attempting to go astern than ahead. It will be necessary, in case a governor is not used, to have some practice in order to be sure that the engine will not be stopped when throwing in the gears, and in order to be able to handle the throttle properly. With a governor, however, the manipulation of the engine is largely a question of properly proportioning the mixture of air and gasoline vapor and of proper adjustment.

52. Oiling and Greasing.—Before starting out on a trip, the grease and oil cups should be filled and all places not fed from the cups oiled. Then all the grease cups should be turned down until a back pressure is felt. The oiling of the timer shaft and of any other isolated place should be done at this time. The shaft bearings are fed from the grease cups, which

should be given a turn once in about 2 hours. A full grease cup should last for a whole day's run.

Oil should drop through the oil cup at the rate of twelve to twenty drops a minute for a new motor and about eight or ten for a motor that has been run enough to be perfectly smooth.

53. The mixing of oil with the fuel is growing rapidly in favor and some makers refuse to guarantee their engines unless this mixture is used. The proportion of oil to gasoline is one to forty if the oil is heavy-bodied, and one to thirty-two if the oil is light. No steam-engine oil should be used, as it will gum up everything; in fact, only the better grades of gas-engine oil should be used. When oil is used in this way, it must be strained in with the gasoline, having been put into the gasoline and thoroughly mixed before the fuel is poured through the strainer into the tank. In this way oil will do the work required of it. The heavier cylinder oils must not be used in this way. In the use of this method the effects require watching. If a very fine gauze screen is used in the pipe-line strainer, it will pick up some of the oil from the mixture and in time clog the strainer; an occasional cleaning will take care of that. The same gumming is apt to take place at the small opening in the float valve and at the needle valve; both can be easily cleaned.

54. When, by accident, an oil cup placed between the carbureter and the cylinders floods back into the mixing chamber, a few primings will generally blow it out through the cylinder. At times the cylinder will be flooded with oil through neglect. When the cylinder is hot, the excess oil causes little inconvenience; with a cold cylinder the oil brings trouble. When there is an excess of oil, priming the engine several times will blow it out. If the sparking points have become foul, the plugs should be taken out and cleaned with an old tooth brush and gasoline. Carbon deposit is the natural result of excess oil or fuel.

REVERSING TWO-CYCLE ENGINES

55. When there is no reverse gear, a jump-spark, two-cycle engine may be reversed without stopping the motor by bringing the timer to very late, so the motor will be running as slow as it can be kept going, then throwing the timer into a very advanced position. The engine will reverse because the advanced-spark position makes the spark occur when the piston is still rising, or on the upward stroke with engine going ahead. Because of the slowness and lack of momentum in the piston, the explosion, occurring before the piston has arrived at the center, is able to drive it back and the motor takes up the cycles backwards, or is reversed. Were the spark created when the piston was in the same place at the time of starting, the engine would start in the reverse direction.

An advanced spark is frequently used, when the engine is driving ahead, for the purpose of obtaining the extra power created by the compression of the charge just as it has been fired, the momentum of the engine being depended on to carry the piston by the center.

56. Reversing on the switch is accomplished largely by becoming familiar with the sound of the motor. In time one can become so accustomed to its sound that the time of the beginning of the upward stroke can be distinguished when the motor is running slowly. To execute the reversal, the circuit at the switch is opened, depriving the cylinder of the spark and the motor immediately slows down. The trained ear of the operator catches the sound of the upward stroke and the switch is thrown into contact; an explosion takes place in the cylinder and instead of completing the upward stroke the piston is pushed back with force enough to make it take up the cycles reversed. On account of its construction, the two-cycle engine runs equally well both ways.

57. Blistered hands are unnecessary from cranking. Gloves are some protection, but with cotton waste held firmly, and not allowed to turn in the hand, it is impossible to raise a blister from any amount of cranking.

STOPPING A GASOLINE ENGINE

58. When the engine is to be stopped, first throw in the compression relief cam or open the relief cocks. The object of relieving the compression is to prevent the engine from running after the electric current is thrown off, the mixture remaining in the cylinders igniting from incandescent particles of carbon attached to the piston or walls of the cylinder. The switch should then be thrown out and the oil cups shut of. When using reversing gears, it is always better to stop in the neutral position, neither going ahead nor astern, for it is usually much easier to release a clutch when the engine is running than after it has been stopped. The gasoline-supply valve, which should always be placed in the supply pipe directly back of the vaporizer or carbureter, should then be closed.

59. Among several reasons for adopting this method of procedure when stopping an engine the following may be mentioned: If the engine is stopped by entirely closing the throttle, its closed position may not be noticed when attempting to start, and with the throttle closed the cylinder will be filled with a charge of burned gas instead of a fresh charge of explosive mixture; the engine should not be stopped with the switch on and the make-and-break electrodes in contact, as the batteries will thus soon be exhausted.

Shutting off the gasoline at the vaporizer by means of the needle valve is extremely bad practice. It is much better and more satisfactory to close the valve or cock in the supply pipe, for should a leak develop at the union in the piping to the carbureter the closing of the needle valve will not prevent gasoline from leaking into the lower part of the boat. Shutting off the supply at the vaporizer in two-cycle engines is more likely to cause crank-case explosions or back fires than in four-cycle engines. Back firing is caused by a too weak mixture of vapor and air, which is slow-burning. In four-cycle engines, more time elapses between the opening of the exhaust and the inlet valves than in two-cycle engines, in which the inlet port is opened almost at the same time as the exhaust. The faster

the two-cycle engine runs, the less time there is between the opening of the two ports and the greater the liability to crank-case explosions or back firing.

60. When shutting down an engine, some operators close the sea cock. This is unnecessary and is liable to cause more harm than good; for, were the engine to be started with the sea cock closed, considerable damage to the engine might be caused by overheating. Rubber hose should not be used for the connection from the pump to the sea cock, and if suitable piping is used there is little if any danger from a leak developing while the engine is not running.

As a precautionary measure, it is always good practice to close the gasoline valve at the tank at the same time it is closed at the vaporizer or carbureter.

STARTING TROUBLES

61. **Tracing the Cause of Failure to Start.**—In a general way, when a motor does not start the first thing to do is to try the spark. This is done by turning the flywheel until the make-and-break or the timer contacts touch. Then, if the buzz of the vibrator is not heard the fault is in the ignition system. If the vibrator sounds with the usual vigor, the gasoline supply should be suspected. The needle valve of the carbureter and the valve at the tank should first be examined; if these are right a priming charge should be put into the cylinders either through the priming cups or squirted through the open petcocks from a small oil can with a point fine enough to project past the turning cock, that the charge may surely go into the cylinder. If the electric circuit is all right the motor will almost surely start after a moment and run either steadily, or until the injected gasoline is used up, for this method will often bring a poor mixture into regular explosions by the heating of the cylinders. It does not all burn with the first explosion.

62. Should the motor stop when the injected gasoline is used up, the shortage of fuel is a surety and the tanks should be

examined. A reflection of one's face may be seen in the gasoline, but there may not be sufficient gasoline in the tank to run the motor. The low level of the fuel should be 6 inches above the level in the carbureter to insure good results if no force feed is employed. In case there is no gauge on the tank, a stick may be put to the bottom and quickly withdrawn; the portion that is wet shows the depth of the fuel. If plenty of fuel is found in the tank, the needle-valve adjustment should next be examined. Should that be found correct the carbureter primer, or tickler, should be pressed several times to ascertain if the gasoline flows freely up to that point. A few drops of overflow, or the absence of overflow will show this. The pressing down of the tickler, or lifting up in some instruments, opens the float valve and flushes the carbureter. If the carbureter does not flush, there is an obstruction in the float valve or the strainer in the pipe line needs cleaning. To clear the float valve move the flushing pin quickly up and down; the free opening of the inlet pipe may dislodge anything small. Not getting a flow of fuel indicates an obstruction too large to pass through the opening; in this case, disconnect the fuel pipe and pass a wire through it into the carbureter. Before connecting the pipe again take off and clean the filter in the pipe line. This is a good time to blow through the pipe line and make sure that all is clear.

63. There is a possibility that the float has been set too high in the carbureter, but in that case the flow of gasoline will have been interfered with from the first. It is also possible, but hardly probable, that the float has not been balanced to lay level and is too light; this also will work wrong from the start. The only other place in which an obstruction can lodge is in the needle valve. To clear this, take out the needle valve entirely and insert a wire, making sure it is directed through the opening by which the gasoline enters. Turning the cock in the line at the tank will show whether the gasoline is flowing from the tank. If the line is now clear and the carbureter is adjusted right, there will be no trouble in starting the motor.

64. Causes of Refusal to Start.—The most frequent causes for a motor not starting are an open switch and a closed valve in the gasoline line either at the tank or at the carbureter.

Sometimes a new engine piston is so tightly fitted that it seems impossible to get the machine going after it has laid idle long enough to let the cylinders cool off. The condition may best be expressed by the term *frozen*. The remedy is to have the spark and all in first-class order and then to squirt into the cylinders a good spoonful of oil and work the piston up and down a number of times. Then, if the engine is primed with gasoline it will almost always start.

Many times engines have been started after long struggles by simply injecting a few squirts of oil into the cylinders. Rocking the wheel two or three times with half turns will have the effect of priming.

65. Tracing for a Weak Spark.—If the engine is cranked or the starting device put in operation, and the motor does not start, the first thing to do is to listen for the vibrator. In case no sound is heard the trouble most likely is in the ignition system. But if the buzzer is heard, the trouble may be in the wiring or spark gap. Under such circumstances prime the cylinders by pouring a small teaspoonful of gasoline into the priming cups, or open the petcock and, if without priming cups, insert the spout of a small oiling can which should be kept full of gasoline for the purpose, and inject into the cylinder three or four squirts from the can. Now wait for about $\frac{1}{2}$ minute for the gasoline to vaporize, then close the switch and crank the wheel. If the engine was running right when last operated, the absence of an explosion under the present conditions indicates that the cylinder is flooded with gasoline or with oil; or it lacks a spark. Try the spark first by disconnecting the wire from the plug, if a high-tension system is used, and, having the switch closed and the timer contacts together so that the vibrator is buzzing, place the end of the secondary wire close to the plug terminal. If a stream of sparks jump $\frac{1}{4}$ inch to the plug the probability is that the trouble is not there.

Next examine the oiler. If the oil cup has been left turned on, that is probably the cause. Some remove excess oil by burning it out with gasoline that has been poured in through the plug hole. Another way is to crank it out. A swab may be introduced through the plug hole. After having thus removed most of the oil explosions to expel what is left are produced more readily by priming than by use of the regular method.

66. If the trouble is not caused by the oil look at the carbureter; dripping from it will indicate that the cylinder may be flooded. In this case, shut off the gasoline at the tank, open the petcock or relief cocks and crank the motor. There will naturally be a smell of gasoline because of what has been injected into the cylinders but that smell should not remain strong after a few turns. If a strong smell continues to come, it indicates flooding, and before many turns, intermittent explosions will commence and the engine take up its cycle of operations.

67. With no overflow at the carbureter and no strong smell of gasoline, try another priming to make sure. There being yet no explosion remove the plug and try it. If the spark jumps across from one point to the other, the trouble is due to lack of strength in the spark which, though it looks ample in the open, has not strength enough to push through the compressed charge within the cylinder in volume enough to cause an explosion. The charge is a good non-conductor and offers so much resistance when the current is jumping across from one point to the other that the oxygen in the air is set on fire and explodes the charge. For instance, a cylinder may contain a piston with a 4-inch stroke and $1\frac{1}{4}$ inches of clearance between the top of the piston and the crown of the cylinder when the piston is at the top of its stroke. This means that a volume of air $5\frac{1}{4}$ inches deep has been compressed into a space of $1\frac{1}{4}$ inches, or about one-fifth of the space it occupied before being compressed, and that the resistance of $5\frac{1}{4}$ inches of air has been crowded into the $1\frac{1}{4}$-inch space. It is now four times harder for the current to jump the gap between the points of the spark plug than it was when the piston was at the bottom

of the stroke. The deduction is, that far more power, or voltage, must be exerted in forcing a spark across a gap in compressed air than in free air. This explains one of the most mysterious troubles that perplex the gas-engine operator, that is, a spark that appears to be ample yet produces no explosion.

68. The cause of the weakness may be found by trying the dry cells with an ammeter, where a battery is used. If five cells are called for by the instructions on the coil and all have fallen to a reading of 12 to 15 amperes, add another cell and the engine will be almost sure to start. A sure test of the strength of the current flowing through the primary circuit is to disconnect the wire anywhere except between the cells and insert an ammeter into the gap made. A reading on the ammeter of anything over ½ ampere tells that there is sufficient strength in the primary circuit. With the amperage reading less than ½ ampere, and the cells altogether reading over 12 the resistance must be looked for in the circuit. The trouble may be due to a joint that is not bright, a connection loosened by vibration, a wire with a kink in it, a wire with the insulation nearly gone, a short-circuit caused by a tool, a water- or oil-soaked wire or switch, or a broken wire that is held together by the insulation not having parted, thus keeping the ends in contact. Take out all ends and brighten them by liberal scraping. Scrape carefully the contacts at the switch. Allow no corrosion to remain on any joints. Set down the terminals on the dry cells with pliers, being careful not to twist so hard that they come off. Make firm the contacts all along the line. Open up and dry out all damp places.

69. Premature Ignition.—Premature ignition may be caused by a weak spark, weak mixture, slow speed, poorly working valve, excess oil or gasoline, a leak of air into the mixture from pipe joints or excess air through the auxiliary air valve, or a misplaced spark adjustment. The weak spark may be discovered on a jump spark by testing as just explained.

In a make-and-break test, the wheel must be turned up until the electrodes, or contact points, come together within the cylinder, then the switch closed and the wire taken off the firing

pin. Now wipe it across the top of the firing pin. If it gives a hard, snappy, good-sized spark that seems to explode as it jumps across when the contact is broken, the spark is all right. The spark at the breaking of contact in a make-and-break is the one that ignites the mixture.

A weak mixture may be caused by too much air or too little gasoline, by a leaking crank-case allowing air to be drawn in, or by the auxiliary air valve sticking on its stem or having a weak spring.

70. When an engine has the spark cut off and still runs furiously the gasoline should be shut off quickly. Lack of fuel is the only thing that will stop it. A deposit of carbon inside the cylinder has taken the form of a point and has been made incandescent by the heat of the explosions. The point will remain glowing and firing the entering charge of gas as long as fuel is supplied. In any case where the engine continues to run for more than two or three cycles after the spark has been cut off, the gasoline, or any fuel, should be shut off at once. The general cause of the carbon deposit is the excessive use of either fuel or cylinder oil. Either will, through poor combustion, make so much smoke that the deposit is left on any place to which it can stick.

71. The easiest temporary remedy in two-cycle engines is to take out the igniter, bring the piston to the height of the upward stroke, then fill the cylinder with kerosene. Now introduce a strong wire, bent to suit the purpose and having a swab on the end, and scour the inside as well as possible. Working the piston up and down will help to clean the cylinder walls. The piston may then be lowered to let the kerosene run out of the exhaust. This treatment should be followed by a liberal allowance of oil for the first few moments' running.

In rare cases, the deposit of carbon may be so great that when the incandescence takes place the entering charge of gas will be exploded before the piston reaches its height on either side. The flywheel then whirls about three-quarters of a turn back and forth in the most violent manner as each charge is exploded.

The only remedy for an extreme case like this is to remove the cylinder head and thoroughly clean the cylinder.

72. Leaks in either joints or in crank-case may be discovered by holding any light substance near them, such as a fluffy string or a small piece of cotton waste. Any suction that will interfere with the mixture is strong enough to draw the fluff against the leak.

Excess air through the auxiliary air valve is from poor adjustment, a weak spring, or a sticking valve stem. If the fault is from poor adjustment, turn the adjusting screw to make the valve a trifle stiffer. If the trouble is a weak spring, it is better to replace it. If from a sticking stem, a little oil or a polish will remedy it.

In the timer, the setscrew, or other fastening device, may have allowed the timer to slip around on the shaft. Or if the timer shaft has been taken out, in replacing it the right teeth in the driving gear may not have been brought together, thereby throwing the spark out of time with the piston, thus causing preignition. If the make-and-break system has a spark adjuster the same thing may have happened to it; or the trip may be working wrong. This may be discovered by taking out the igniter plug and inserting a stick reaching down to the top of the piston. Bring the piston to the highest point of the upward stroke, which is readily found by the stick as it is pushed up. The igniter trip should have snapped about $\frac{1}{8}$ inch before the piston reached the height of the upward stroke. If it has not it should be readjusted.

73. Motor Binding.—With the petcocks open, the motor should crank easily; if it does not there is something wrong. The first thing to be suspected is the stuffingbox. Unscrew the locknut and loosen the stuffingbox, then try the cranking. If the turning is still hard, look at the oil and grease, giving the grease cups a good twist down. A few turns should limber up any bearings. With no easing of the strain, try the packing nut on the pump. If nothing appears to be wrong, examine all along the line of the shaft; it may have become bent and be working against the wood. If it is in good order, either

the main bearings or the piston have been overheated and roughened. Oil, grease, and hand working should put them in working condition; if not, they will have to be examined.

CARE OF ENGINE

LAYING UP ENGINE FOR THE WINTER

74. As the cold weather comes on care should be taken that after returning from a run the water is drawn off from the entire circulation. This is necessary in order to prevent freezing. When housing the boat for the winter, disconnect all pipes in which water can lodge and blow out the water. Empty the carbureter and tanks. Put all of the electric outfit in a dry place, where there is some warmth if possible; the coils will be better for it in the spring. Take off all fittings that are movable; if prowlers can get near the boat, even the propeller will not be safe. Unscrew the cylinder head and give the inside of the cylinder a good cleaning, removing all carbon and gummed oil, particularly back of the piston rings. Open the crank-case and clean and flush it. Put on the cylinder heads, fill the cylinders with oil; the oil will not evaporate, consequently will not gum, and the finish on the cylinder walls will be preserved. Any parts of the engine that were painted to preserve it from rust should be touched up; the other parts should be cleaned of all dirt and smeared with a thin coating of grease. Throw a canvas over the whole and fasten it down snugly. Rub up the tools and smear them with grease.

75. Cleaning the motor is generally the least congenial part of power boating. It can be made more agreeable, however, by using a paint brush, with a long handle, that has been dipped in gasoline. This method enables one to reach all sorts of places otherwise inaccessible and is quick and does the work. The disadvantage is that it is more or less dangerous, particularly if the operator or a bystander wishes to smoke in the vicinity during the operation. Neither should it be done except in the open air. The liability to trouble is then greatly reduced.

GRINDING AND SETTING VALVES

76. Valve Grinding.—The exit of the hot gases through the exhaust valve has a scoring effect on the edges of the opening; the hot blast also affects the edges of the intake valve, roughening the valve and the valve seat. This roughening must be attended to or it will turn into pitting with a consequent increase in the labor of grinding them smooth.

To grind the valves different compounds are used. They rate as coarse, medium, and fine. The coarse kind is apt to be emery or a mixture of it. The medium kind is generally ground glass. For the finer grinding, such as in the float valve or the needle valve in carbureters, crocus, or rottenstone, is used. The grinding material should be mixed with a moderately thin oil to the consistency of heavy varnish.

For coarse scoring or pitting of outlet and inlet valves use the coarse material, and finish up with the ground glass. Before starting to grind take out the valve and put into the cylinder a piece of cloth to catch any of the grinding material that drops in. This is necessary to protect the piston and cylinder from the emery or glass and the quick grind that would take place with them inside.

77. For twirling the valve on the seat when grinding, set the tool used into a bit stalk and grind by turning complete revolutions. In most cases it is well to reverse the motion after every several revolutions. Continue this with the coarse or the medium grinder until a smooth face is secured, then polish with ground glass mixed with thin oil. While grinding, be sure and preserve a perfectly perpendicular position to the bit stalk or the valves will grind out of true. With valves in which a cross-slot is provided for the twisting, there is apt to be a pit that was used in turning the valve when made. The pit can be made to serve a useful purpose by filing to a point the end of the screwdriver used in the grinding, and resting the point in the pit. In this way the holding of the bit stalk in an absolute perpendicular position will not be of such importance.

78. Valve Setting.—To correctly set the valves, the exact time at which each piston is at the top of the stroke should be marked on the flywheel. If these marks are not already on the wheel, they may be placed there by taking a plug out of each cylinder and testing the pistons one at a time. Make the test by dropping a thin stick through to the top of the piston. Crank the engine until the stick rises through the plug hole as far as it will; then place a mark on top of the wheel and have it directly opposite a mark placed on whatever is stationary back of the wheel. If the plug hole is not so placed that a stick will drop through to the piston the correct time may be taken by the crank rising to its highest point, this time being the same as that of the piston.

79. The inlet valve should open just a trifle late on the top center of the piston stroke, and close a trifle late on the bottom center. By late is meant just past the center in the direction in which the wheel revolves.

The outlet valve, or exhaust valve, should open a trifle early on the bottom center of the piston stroke and close a trifle late on the top center.

There should be no need of resetting the valves except because of the wear incident to grinding. This wear is regulated by the adjusting nut on the push rod. Between the push rod and the valve stem the clearance should be $\frac{1}{32}$ inch or less; in most cases it should be less. The proper distance is given by the makers. All makers do not use the same clearance and some provide for clearance of only the thickness of a visiting card.

CARE OF WATER-CIRCULATION SYSTEM

80. Care of Pumps.—The water pumps located in the cooling system need attention at times. The packing will get worn and the suction diminish because of air getting through it. In such cases, loosen the packing nut and take out the old packing. Twine in some regularly made packing or, what is easier, some lamp wicking of the soft stringy kind smeared with soft graphite. When screwing the packing nut home be

careful not to put too much strength into the operation, or it will bind and cut down the speed of the engine. Try this by cranking the engine after packing.

Pumps will sometimes get out of line with the shaft; this must be corrected at once. The result will be lack of cooling water for the cylinders with the resulting trouble. It is a good plan to take off the head-nut and drop some oil on the top of the plunger occasionally.

81. On rare occasions the pump will give out in a manner that precludes repairs. The motor should at once be shut off and, if advisable, the anchor dropped. It is always well to have in the boat a length of medium-sized hose. The water system should be disjointed in whatever place will serve best and the hose attached by some means. If the hose is too large, it can be reduced by slitting and wrapping with rubber tape; if it is small, it can be slit, the ends lapped over the pipe and the whole bound with rubber tape. The connection must be made between the pump and the cylinders if possible, though this is not absolutely necessary, as water can be sent in either direction through the cylinders and the purpose of cooling be accomplished. After the length of pipe has been connected raise one end and fasten it to something having a higher elevation than the top of the cylinders. Place a funnel in the opening of the pipe and pour water in with frequency enough to keep it coming from the other side of the cylinders fairly cool. It can be steaming and no harm will be done.

Another way is to fasten a funnel to the open end of the pipe and make it fast alongside at the water-line with the open end pointing in the direction in which the boat is moving. In this method the speed of the boat must be over 8 miles an hour to lift the water to the engine cylinders.

82. Troubles in Water Circulation.—The lack of water in the pipes is manifested by the smell, by a smoky vapor rising from the water-jackets or the exhaust pipes, or by a difference in the sound coming from the motor. Generally, a quick remedy is to rap the valves on either side of the pump, as the

main trouble is caused by particles lodging in the valves and the rapping will in most cases jar them free.

If this is ineffective, the trouble may be with the screen at the inlet on the bottom of the boat. In this case, reach over the side and scrape the screen, using a long stick. If out of reach with a stick, back the boat and throw the obstruction off. Another way is to pass a rope under the boat, and, holding both ends, seesaw it across the screen.

Should the screen be clear, see if there is dirt in either valve. The next place an obstruction can lodge is in the small pipes where the water enters the water-jacket. Often these are provided with ground joints held together by means of a bolt passing from bottom to top through the interior. This makes the available passage very small and weeds can lodge in it. The bolt holding the joint together is frequently made of steel or iron and rusts quickly; brass or bronze bolts should be used.

The interior between the water-jacket and the cylinder will in time corrode and the sediment clog the water circulation, particularly at the outlet on the outlet side of the cylinder. The sediment from this cause and from scaling should be cleaned out every season. The exhaust pipes are usually iron, which scale badly after a few years and should be replaced. The muffler also is constantly scaling when it once begins and will choke the exit of water and gases.

83. Between the engine and the connection with the inlet for the water circulation there should be a short length of rubber pipe to take up the vibration. Another piece of rubber pipe must be between the engine and the pump. After long standing the pump and pipes may be entirely dry. It is well then to take off the head-nut and pour in a few drops of oil; also, a liberal supply of water to fill the pipes and help the plunger to start the supply should be poured in. It usually takes a minute or more to send the water out of the exhaust, as the whole water-jacket must be filled before that can happen.

When running in a seaway that will lift the sides or ends of the boat clear of the water, the intake may be lifted out and the continuity of the flow be broken. This condition will be

made known by the different sound that will come from the exhaust. This will cause no harm, as there is always water enough in the pipes and jackets to do all the cooling necessary.

84. The water-jacket sometimes becomes so corroded that it will leak. Temporary repairs can be made by stopping the engine and letting the water go below the level of the leak, and then drying off the surface and binding it with bicycle repair tape. A liberal use of the drainage cock will get rid of much sediment.

After there has been trouble by heating from lack of water do not turn any water into the jacket until the cylinder has become cooled. The cold water is apt to crack the hot metal.

A fair percentage of water should be allowed to go through the muffler to keep it from overheating. In cold weather, make it a rule to open the drainage cock at the end of every run. It will keep the pipes or jacket from bursting.

85. After taking off the cylinder head a few times without renewing the gasket, water may appear in the cylinder, and be found on the sparking points. The presence of water in such intense heat creates a vapor that dilutes the gasoline vapor until it is useless. When any considerable quantity of water is found to be in the cylinders take off the heads and examine the gasket. The probability is that it needs renewing.

When water appears in the bottom of the boat of a higher temperature than the surrounding sea the exhaust will be found leaking in some part. Any unaccountable leak in the boat may be looked for around the water intake as it enters the hull. Between the part attached to the bottom of the boat and the pipe connected to it, there is a nipple; this nipple may loosen through vibration and shake out the lead packing. For this trouble wrap the joint with a closely woven cloth smeared with grease, and lash it firmly and thickly with fine twine.

TOOLS AND NECESSARIES

86. A few tools are always necessary in running a marine gas engine to get at or remove parts that may have to be taken down for adjustment, repair, or inspection. The following is a list of tools that will be found useful for this purpose:

One medium-sized Stilson wrench for stuffingbox and pipes.

One 6-inch Stilson.

One 6-inch monkeywrench.

One 12-inch monkeywrench.

One bicycle wrench.

NOTE. — Instead of these a set of S wrenches bought specially to fit every sized nut or bolt on the boat is greatly in favor.

A key wrench for use on nuts on side plates is very useful. It may also be used for nuts in recesses when one sees the head of the nut instead of the side of it.

One small vise.

Two sizes of screwdrivers.

One machinists' hammer, with round end and flat end.

One large file with round and flat sides.

One small three-cornered file.

One bit stalk with assorted tools, and two or three sizes of steel drills.

One hack saw.

One 2-foot rule.

One pair of gas pliers, for use on terminals and other places.

One pair of wire cutters.

One calking iron.

One tool handle, the handle filled with tools.

One cold chisel.

Waterproof cases for rolling these tools in can be bought.

Shellac and hard soap for temporary gasoline repairs.

Bicycle, or rubber-gummed, tape.

Spare wire for circuits.

Two kinds of packing for the stuffingbox, and a soft wicking kind for the pump.

Some graphite.

An extra spark plug and extra cells for the battery.

An ammeter.

One copper oil can with long spout.

One copper squirt oil can, for oil.

One squirt oil can to be kept filled with gasoline for priming, cleaning the hands, and other uses.

MANAGEMENT OF MARINE GASOLINE ENGINES

(PART 2)

TROUBLES AND REMEDIES

MARINE ENGINE TROUBLES

LEAKY CYLINDERS

1. Testing the Compression.—One source of trouble in a marine gasoline engine is loss of compression in one or all of the cylinders, which may be due to any one of a variety of causes and results in a loss of power or perhaps in a failure to start the engine. An easy method to test the compression in the cylinder of an engine, is to try them, one at a time, in the following manner:

Close the petcock and holding the piston at the top of its stroke for about ½ minute let it go suddenly; if it does not bound back the cylinder leaks and must be examined. To make sure try again and see if the piston will go by the center with a little extra exertion. Then try it by holding the piston for 1 minute. If the piston slides by with almost no extra effort it should be attended to if good results are desired. Try each cylinder separately, keeping the cocks open on the others.

In the case of open-base engines, lack of compression will make itself known by black smoke issuing from the crank-case.

2. Lack of compression is a trouble that seldom comes suddenly, and has probably been making itself manifest for

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some time by the forming of little bubbles about joints or gaskets. However, it may come suddenly just after some part has been taken off because the gasket of that part was worn out or it has been fractured in the operation; either will produce the same result, which is, no compression, and consequently no start or a hard one with poor results.

When under way and a leak from the cylinder is suspected, smear the place with oil; if there is a leak, bubbles will force up through the oil.

The side thrust motion to a piston against the walls of cylinders will in time cause a loss of compression; the remedy for this is to have the cylinder reground. This makes the cylinder of greater diameter and may require a different size of ring.

3. Use of Graphite for Poor Compression.—When compression is only moderately poor, but there is difficulty in starting the engine on account of it, a mixture of graphite flux and oil may be squirted into the cylinders. This mixture consists of one part flux to three parts oil. The mixture will settle in the vacant places about the piston and hold the gases; then when the cylinders and piston have become heated the compression will improve of itself. The graphite is a splendid lubricant.

4. Leaky Gaskets.—All the openings into the cylinder are made tight by the use of gaskets or snug-fitting threads. Leaks can be discovered by smearing oil around the joinings. If there is an escape of gas the oil will bubble up. In the case of screwed parts they must be set up tighter or leaded.

The parts protected by gaskets will, when leaking, require new ones. Temporary gaskets may be made of thick brown paper smeared with shellac on both sides; if there is no shellac on board oil will answer in the majority of cases. The shellacked brown paper makes a very efficient gasket and is sometimes used for permanent ones.

Probably the wire-lined asbestos gasket is the most efficient one in use on the average boat. For cylinder heads where many bolts go through the gasket, a punch should be bought

for the size hole required; this saves much labor. For this gasket, place a piece of the material on the cylinder and mark the holes; punch them out and put the piece down over the bolts and with the round end of a hammer rap all around the edges until the gasket is cut out. The asbestos will be cut when hammered over the edge of metal. For irregular gaskets lay the gasket material down on the part and holding it from slipping rap with the round end of the hammer. Good-fitting gaskets can always be made in this way.

When it is certain that all gaskets about the cylinder are in good order and the tanks and carbureter have been cleaned thoroughly, and yet there is water in the cylinder, it is fairly certain that the walls of the cylinder leak. This is a rare occurrence and the best and surest remedy is to return the cylinder to the manufacturer.

5. Miscellaneous Leaks.—If a leak is suspected in the intake pipe between the carbureter and the cylinder, oil placed about the spot will develop the leak by the oil being drawn in if a leak exists. Excessive valve lift will give the same result as a leak. A leaky inlet valve will result in back firing and weak explosions. A leaky exhaust valve will result in weak explosions and in explosions in the exhaust pipes. Vibration can loosen the brazing in the manifold air intake and allow a suction of air, thus giving a weak mixture. Carbon caused by too much oil, also from too much gasoline, will shorten the life of cylinders rapidly.

When a cylinder is out of commission and the engine must be kept running, open the petcocks of that cylinder.

PISTON-RING TROUBLES

6. Removing Carbon.—Piston rings wear slowly and a number of seasons are required to produce any effect on them. Carbon is their greatest enemy. To prevent carbon, the cylinders should be given two or three tablespoonfuls of kerosene each week, or twice a week if the engine is operated to any extent. Some authorities advocate putting the kerosene in

and letting it stay overnight, with the idea that the evaporation of the kerosene overnight will not leave any cause for a poor mixture in the morning. Another method is to put the kerosene into the cylinder and work the engine by hand a number of times for the purpose of washing the inside of the cylinder and working the kerosene down through the rings. More kerosene should then be put in for the flushing effect, or to get rid of what has been dislodged. This should be followed by a number of drops of cylinder oil. Kerosene is a good cleaner, but it will be followed by rust if left to dry by itself. The face of a well-kept cylinder should be as polished as a mirror. The polish is necessary if the cylinder is to give good service. The slow evaporation of kerosene on it will do no good.

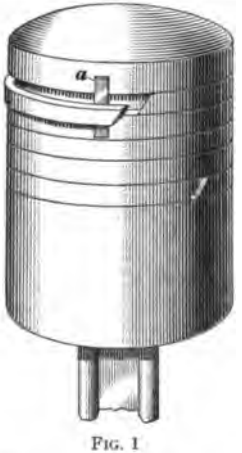

FIG. 1

7. Regulation carbon removers are apt to be made of one part aceton and nine parts wood alcohol. They will thoroughly remove carbon, but the polish is apt to go with the carbon. When using the regular carbon remover put it into one cylinder at a time, but leave it in only ½ hour. When that cylinder is cleaned, start the motor and give that cylinder a little extra oil; then clean the rest in turn.

8. Removing Piston and Rings. When it is necessary to take out the piston and clean the rings, the best way is to put the whole piston into a can, or vessel of some kind, containing a quantity of kerosene. Then work the rings back and forth in their grooves, sousing them up and down occasionally to wash the carbon from behind. When the washing is ended it will not take long to dry the kerosene; this is the time the rust starts. Put some oil into the rings and work them a little; a mere skimming of oil is all that is required. Wipe the piston all over with a cloth on which a few drops of oil has been placed. This will prevent rust and put the piston in good shape.

To take off the rings some pieces of clock spring or brass should be provided. Pry one end of the ring up gently, with a piece of very hard wood if it can be secured, until the flat band of the clock spring *a* can be slipped under it, as shown in Fig. 1. Slide the piece of spring along but before the end of the ring has come down into the groove slip another piece of spring under it, and so on until the ring is resting entirely on pieces of clock spring; then slip the ring off the piston.

When a sudden loss of compression, or a hard resistance to running is manifested, it may be due to carbon having caked and the play of the rings thereby stopped. Under these circumstances, there is danger of the rings being broken.

VALVE TROUBLES

9. The opening of the inlet valve too early will cause back firing. This is due to the ignition of the fresh charge in the inlet pipe and carbureter by the flame remaining in the cylinder from the previous explosion.

The strength of a valve spring may be tried by slipping the end of a long screwdriver or similar tool under one end of it and compressing it. If found weak, compared to the resistance of the others, put in another spring. A spring can be strengthened temporarily by stretching it.

The staying open of a valve when it should close may be due to a weak spring but it is more apt to be from a bent stem or from carbon on the stem. The carbon may be removed from the stem by soaking it in kerosene and tapping it out, having a piece of wood between the hammer and the valve stem.

CRANK-CASE DIFFICULTIES

10. Crank-Case Requirements.—The crank-case must of necessity be air-tight in a two-cycle engine, for in it the fresh charge of mixture is to be compressed to the extent of from 2 to 7 pounds, according to the make of the motor. To be efficient it must also be free from excess oil, and should be entirely free from sediment. Sediment in the crank-case will

be picked up by the lower end of the connecting-rod in its revolutions and carried by the splashing to the sides of the piston, and by the piston to the walls of the cylinder. Smoke issuing from the crank-case indicates that the crank-case is not air-tight and that the piston is leaking exploded gas past its rings from the cylinder.

11. Explosions in the crank-case of a two-cycle engine are due to a lack of fuel in the mixture and are caused in the same manner as back firing in the inlet pipe. All crank-cases should have a drainage cock so that they can be cleaned frequently. Where the chamber is bolted together horizontally through the center, the joint may be made tight by coating both sides of the gasket with graphite. The oil in the crank-case should rise high enough to be ½ inch deep on the lower ends of the brasses on the connecting-rod.

12. Cleaning the Crank-Case.—In many cases, the crank-case of a two-cycle engine will become so filled with oil, gasoline, and dirt, that a proper mixture is impossible. It should first be drained by means of a drainage cock, or a nut, at the bottom, which may be opened or taken off. It should then be flushed out well with gasoline to clean it of dirt and grit. When the cleaning operation is over some oil should be put into the case so that the connecting-rod can splash it up and oil the brasses, otherwise the brasses may be burned out. A handy way to take the excess oil out of the crank-case is by means of long-stemmed squirt guns, or syringes. A clever method of oiling the crank-shaft bearings is with a squirt-gun oil cup. They are rigidly attached to the crank-cases and the oil squirted in with a plunger action.

13. Loss of Base Compression.—In two-cycle motors, there may be loss of compression in the crank-chamber where the shaft enters and leaves the base. The check-valve in the base of two-port, two-cycle motors may not seat well because of dirt, carbon from base explosions, or from a weak spring, thus causing loss of compression. There should be from 2 to 5 pounds compression in the crank-chamber according to the

design of the engine. If there is not, the mixture, which is drawn into the base and compressed, will not be forced into the cylinder with enough vigor to expel all the burned gases. This will leave the next charge so weak that it will explode weakly or not explode at all, or, it may explode so slowly that the fire will linger until the next charge is entering the cylinder and by firing it, cause a back fire into the crank-chamber or the carbureter.

The loss of compression may be due to leaky gaskets of the crank-chamber, which may be worn or may have been frayed when the chamber was bolted into place.

CLUTCH TROUBLES

14. The principal fault with clutches is their tendency to slip. In many cases this comes from oil getting into the disks or the band, supposing that the clutches are of the dry type. In other cases the slip is from wear or because the power of the engine is greater than the clutch was designed for. The reason the clutch will not work is that when all the pressure that can be brought to bear on it is in force it is not bound hard enough to take up the load and drive the boat.

In cases of emergency, the thing to do is to release the clutch and place between the bands or the disk nails, small tools, or anything that is strong enough not to be torn to pieces when the engine is started. If they can be so placed that they will stay in position until the engine is started, and will hold their place during the moment of becoming engaged, the engine can be started and the clutch thrown in. The object of inserting the nails or small tools is to take up the wear and force the clutch to become fully engaged before the entire compressive force is thrown upon it when the lever is pushed in.

The probability is that nothing can be made to stay between the clutch surfaces when the clutch is thrown in after the engine is started; therefore, the pieces must be inserted and the clutch jammed up solid before the engine is started. There is then no chance to reverse the clutch. Some boats carry a length of shafting made to insert in the place occupied by the

clutch. If the clutch goes wrong it is taken out and the short length of shaft is inserted in its place.

15. If the engine is too powerful to be started with a fixed shaft in the ordinary way, some means of leverage should be applied to the crank to get the pistons on two of the cylinders up to and a trifle beyond compression, then the switch thrown in and a spark produced. If this cannot be done and a short tow can be secured from a passing vessel the engine will be easily started during the towing process, as the towing will not only relieve the resistance but will perhaps start the engine by the pressure on the propeller without assistance from the operator.

16. If there is no emergency, it is better not to place anything in the clutch as doing so is apt to damage the clutch. It is better to secure a tow and then send the clutch to the repair shop. A clutch slipping because of oil can be washed with gasoline, or dirt or sand may be inserted, although the latter is not good practice as it might destroy the clutch.

PROPELLER RACING

17. In a sharp head sea as the boat lifts over the crest of a wave and begins the downward plunge the propeller will come out of the water and being relieved of the resistance the engine will race at terrific speed and is consequently damaged. If the sea is of such a nature that this is liable to happen frequently, the course should be changed so as to send the boat over the crests in a diagonal direction. In doing that, the strain on the engine, also the boat, is lessened and the rearing and subsequent fall and pound are very much modified. After the boat has been on the new course for a while, the proper course to be run can be maintained by shifting the course so that the seas will be on the other bow. In this way the boat beats to windward the same as is done in a sail boat.

STUFFINGBOX AND BEARING TROUBLES

18. Leaky Stuffingbox.—Leaks in the stuffingbox are frequent. When packing them one should use the square packing that is provided for the purpose by the supply houses, but before putting in place the packing should have a liberal quantity of graphite spread over it. The packing should then be screwed up moderately tight. Before tightening the setnut, or locknut, the petcocks on the cylinders must be opened and the wheel thrown over, being sure that there is no spark. If the wheel turns too easily, the stuffingbox can be set up a trifle tighter. If the wheel turns hard, the stuffingbox should be loosened until the wheel feels right. The stuffingbox should be set a little stiff on account of subsequent loosening.

This packing will last a season. When on a trip it is sometimes necessary to renew the packing. In such cases, when tightening up care must be taken not to strip the threads or the regular packing will not stay in. Should the threads be stripped, the box may be packed by smearing some shredded marlin or cotton waste with grease or graphite and pressing small threads of this packing between the shaft and the box with the point of a knife. In order to do this the stern of the boat should be run up on the beach, but the part of the stuffingbox that was uninjured may be packed with the regular packing. With an inside stuffingbox it is not necessary to haul the stern of the boat up on the beach to get at it. After setting up on the stuffingbox nut the amount of resistance to cranking will tell if the stuffingbox has been set up too tight.

19. Sand in Stuffingbox.—It is bad for the engine and for the shaft to send the boat through mud or sand and particularly to back it through, as is the habit with some when a spot that is just too shoal for the boat is encountered. The backing of the boat through sand is in reality dredging a channel with the propeller. During the process sand is thrown into the water circulation and works into the stuffingbox much to the detriment of both. A little sand in the stuffingbox will

cut the shaft so quickly that the propeller will be wobbling in a short time. The result is such vibration and strain that the shaft will need to be replaced or reversed.

20. Hot Bearings.—When a bearing has run hot, it is not wise to try to cool the bearing, rather the shaft that runs in it should be cooled. The effect of cooling the bearing will be to shrink it on to the swollen shaft, which will result either in a bad seizing of the shaft by the bearing or in a cracked bearing. Water, ice, or whatever may be in use may be applied to the shaft until it has cooled at least to a temperature that will not burn the hand. In the process the bearing is apt to cool nearly as fast as the shaft. Rather than to risk cooling by commencing with the bearing, it is better to sit down and wait for the air to do the cooling. After a case of this kind, it is well to give that particular bearing an overdose of oil, as the heating disturbs the polish and smooth running of the shaft.

KNOCKING OR POUNDING

21. The ignition of the charge before the piston has arrived at the top of the compression stroke will cause the cylinder to give out a metallic sound. Advancing the spark too far will also produce this result. Next to the advanced spark, a loose bearing in the lower end of the connecting-rod is the most prolific source of knocking; that this is the cause can be detected by opening the petcocks and rocking the flywheel back and forth with the suspected crank in an approximately horizontal position. The remedy is to remove from between the halves of the bearing one or two shims as is necessary in order to bring the shaft to a tight bearing. If there are no shims, the faces on one side of the bearing should be filed down until the bearing can be brought to a fit. Should the operator be unskilled with a file, and few amateurs are skilful enough for this, it is better to have the work done by a machinist. When it is done two or three shims should be put in so that the regulating can be done in the boathouse by the operator the next time.

22. There is seldom trouble with the small end of the connecting-rod. There is sometimes, however, trouble from a nut or a screw falling out of the connecting-rod brasses, or elsewhere, and dropping into the crank-chamber where it is liable to do injury. If any unusual noise is heard from that direction, the motor should be stopped at once and an investigation made. The trouble may be discovered by opening the switch and rocking the motor by hand. If there is any trouble, a few turns of the flywheel will develop it. Should a nut or screw have fallen into the crank-chamber, it is apt to break almost anything, movable or fastened.

23. A loose flywheel will produce a sound as if the bottom of the boat was being pounded out, but it is not so serious as the sounds indicate. However, before going out for another run it should be attended to. Generally a resetting of the key is all that is needed and the flywheel may be set up tight by the operator.

The pump eccentric may cause a knock for want of grease. The pump may knock because of the packing being too tight; or for want of a few drops of oil being poured into the packing.

The loss of a ball or two in the thrust bearing may produce a knock. If missing, the balls should be restored at once.

24. A shaft out of true will make a good sized pound. It may be learned if this is the cause by watching the shaft as it revolves. When out of true the shaft must be taken out and straightened. A bend in the shaft can be discovered by stretching a length of strong linen or silk thread along the shaft, holding the ends taut over the ends of the shaft. The shaft may be straightened by laying it on a long straight stick of timber with the bent side of the shaft arching upwards and hammering it with a sledge, holding a block of wood between the shaft and the hammer. A block of wood about 3 inches by 4 inches will answer. By repeatedly testing the shaft with the thread it will be found that a few minutes will suffice to do work as well as can be done in a shop.

It may be well now to examine the ends of the shaft and see whether it has become scored at the stuffingbox. If it has,

the shaft should be turned end for end and grooved for the key, then the propeller put on and, with a steel drill, a hole bored for the setscrew. If the propeller has been put on with a taper bore, it will have to be bored in the shop.

25. During a run one or more of the propeller blades may have been bent by coming in contact with a log or other obstruction. The blade being of soft metal will bend easily. The result is apt to be more or less of a pound and a pronounced vibration. Nothing can be done but get into the nearest harbor as soon as possible and have the propeller taken off. The blade can then be bent back to place, or nearly so, by laying it on a heavy block of wood and straightening it with a hammer, interposing another piece of wood between the hammer and the blade.

The bolting to the base of the motor will sometimes work loose and cause a pound. This will also cause lack of compression in the base.

Loosening of the engine-bed bolts will create either a pound or excessive vibration. If the bolt holes or lagscrew holes have worked large it is better to put in new bed pieces.

Back pressure, from the outboard end of the exhaust being suddenly depressed as in wave motion or, by having too much weight on the stern will cause pounding. Too much water lying in the muffler will cause a pound each time the gas forces itself through the water.

26. One should learn as soon as possible to distinguish between the different sounds given out by the motor. By becoming accustomed to the regular or normal sounds one will the more readily notice an irregular sound and be warned of impending trouble. This familiarity with the normal noises of the engine can be cultivated to such an extent that the least variation in the change of the mixture, or an excess or lack of oil will at once attract the attention of the operator.

Lack of oil in the oil cups or of water in the cylinder jacket may sometimes be discovered by a peculiar sound coming from the cylinders. The change in sound is caused by the swelling of the piston with heat and if it is not attended to at once a

heavy pound will develop and the engine will soon come to a stop.

If the cause of the pound is lack of oil, the piston will swell from the internal heat but the outside of the jacket will remain cool. If the pound is from lack of water, it is probable that by the time the engine is stopped the water-jacket and the whole machine will be smoking and too hot to rest the hand on. Water should not be run through the jacket at once because it might crack the cylinder. The engine must first be cooled, but while it is cooling the pump valves should be cleared and the water strainer on the bottom of the boat scraped clean. The motor is then started and given a quantity of oil for some time. It is presumed that the water circulation is all right.

MISCELLANEOUS TROUBLES

27. Engine Running Regular but Weak.—If the engine runs smoothly but the explosions are weak, the cause may be any one of the following: The auxiliary air valve not working, poor mixture, lack of oil in some part, dirty contacts in coil or timer, poor compression, reduced lift of intake valve, muffler or exhaust choked with carbon or scale, vibrator out of adjustment, weak inlet-valve spring, a late spark, too much gasoline.

28. Skipping.—The principal causes of skipping are, a broken wire, which is touching at the ends as it vibrates; a loose connection, which by vibrating can make a hit-and-miss connection; or a poorly adjusted vibrator. The chances are that the trouble is caused by one of these conditions. The broken wire is the hardest of these troubles to locate. It is easiest found by taking the wire between the finger and thumb and running along the whole circuit. A break in the wire feels like a dent under the insulation. A loose connection may be located by pulling gently in both directions as the fingers slip over each connection. It is presumed that the battery, or magneto, is known to be in good condition. Too much stress cannot be laid upon the use of an ammeter as a trouble saver.

It should be used before each trip, for the time necessary for its use need be not over 1 minute.

29. Skipping may also come from sooty spark plugs or from water in the gasoline. A short circuit in the plug may cause skipping but it is more apt to stop the engine entirely. The short circuit will be caused by a cracked porcelain or mica; by a coating of water or oil; or by oil having penetrated the insulation. It may also be caused by an intermittent strength of mixture caused by a sticking auxiliary air valve on the carbureter; an intermittent supply of gasoline caused by dirt in either the float valve or the needle valve; a loose timer, which can be seen by watching it when revolving at slow speed; the contact points on the vibrator being pitted or sticking; an intermittent short circuit caused by spray on the spark plug or entering carbureter; a poorly insulated wire swaying or coming occasionally in contact with anything wet, or of metal. Frequently a tool may lay in a position that will occasionally cause it to make a short circuit, or stop the engine. A sticking inlet or exhaust valve, caused by soot, may produce skipping.

30. The other conditions that will cause misfiring are not apt to occur suddenly. The operator of an engine is likely to know that the brushes of the magneto or distributer are worn or dirty, or that the timer shaft is not running true. All the parts of the different systems should be glanced at frequently and if anything attracts the attention an inspection should follow. Water in any form will cause skipping, but more particularly in the form of salt spray. When spray is flying freely, skipping need be given little attention unless it becomes too frequent. Then the entire system of wires, the spark plugs, and the carbureter should be covered. The skipping from this cause will decrease as soon as the wires have dried.

31. Slowing Down and Stopping.—Slowing down and stopping may be caused by the vent of the gasoline tank getting closed; this will gradually create a vacuum in the tank as the fuel is used. The result, as the vacuum is made more perfect by the withdrawal of the fuel, is that the gasoline is held in

suspension and cannot flow. Another cause of a gradual slowing down and stopping is too rich a mixture. This gradually coats the plugs with soot and chokes the cylinder. Sometimes, from the same cause, the engine will slow down, then take a spurt and slow down again. A loose valve on the gasoline supply line will jar closed at times and bring the engine to a stop.

Sudden stopping may be due to something jarred loose in the wiring circuit, a gasoline valve jarred closed, fuel used up, dirt in the gasoline line, waste in the carbureter air intakes, dry piston, water circulation interfered with, or a dry bearing.

FUEL AND CARBURETER TROUBLES

USE OF GASOLINE

32. Danger From Gasoline Fires.—When using gasoline the nature of the fuel should be remembered. The gas, or vapor, that it makes is heavier than air and will overflow from a bowl just the same as too much water. Gasoline spilled on the top of a tank in filling will take itself overboard through the drainage pipe, when one is there. If it does not flow overboard but is allowed to stand, the gasoline quickly disappears in the form of vapor, which flows down the sides of the tank to the floor of the boat and along that to whatever openings it can find into the bilges underneath, where it will lie for even a year, ready to explode, unless it is blown out. It can easily be blown out by opening up the boat any breezy day and allowing the wind to sweep through it. If the boat is a cabin cruiser, the vapor may be driven out with a light current of air, by using a canvas air funnel and directing the air into the bilges or by using blowers operated from the engine.

Where the boat is not equipped with a dynamo for lighting, care should be taken not to use candles or other exposed flame in places where gasoline vapor is likely to exist. If necessary to use light in such places a few discarded dry cells may be connected in series to furnish current for a 1-candlepower electric light. On the end of a long wire, this can be poked into any

corner or crevice, or hung into boxes and spaces that would not permit a lantern or other kind of light. The pocket flash lights are also handy, but not so convenient because they must be held in the hand.

33. Any fuel in the nature of oil will, when on fire, spread and enlarge the area of flame if an attempt is made to quench it with water. No fire can burn without air, hence a good way to extinguish a gasoline fire is to deprive it of air. This may be accomplished in various ways. Many extinguishers contain a powder or a liquid that will smother flames quickly. A coat, blanket, or similar article thrown over the flames will smother them at once: Perhaps the most effective of all extinguishers is sand mixed with salt, because should the others be lacking in quantity to cover the whole of the flame, the entire effort may have been made in vain. But with the sand every part of the flame covered by it is effectually extinguished, leaving only the edges to be cared for.

34. All pipes leading from the cylinder should be wrapped in asbestos or other suitable material. Without water passing through the exhaust passages, the pipes and muffler may become red hot and prove dangerous because of the liability to set afire gases and any wood near which the exhaust may pass. The packing should be inspected frequently. It is good practice to have part of the circulation water to go through both exhaust and muffler.

35. Gasoline Fumes.—Gasoline fumes are poisonous either before or after being exploded, and should not be breathed in a confined place. If they exist in a cabin, the space must be thoroughly ventilated. Open ports are good for the purpose but an air funnel is better because it has more driving power and the draft can be directed where wanted.

Even when running in a moderate breeze the fumes have produced serious results. If, as sometimes happens, the speed of the wind and of the boat are the same and the vapor clings about the occupants, as indicated by its odor, it is good practice to change the course of the boat enough to bring the wind from a different quarter.

Knowing that the fumes are dangerous, they should be dispelled by ventilating. Their presence in a cabin is either from a cracked muffler, disjointed exhaust pipe, or open petcocks. Petcocks are frequently opened with the idea of relieving the cylinders, but if cylinders need relieving it should be done by cutting down the fuel supply.

36. Water in Gasoline.—Water and dirt are found in the chamois strainer frequently after gasoline has been poured into the tank, showing the presence of water in the gasoline when it was bought. However, there is another source of water, and one that illustrates the importance of using a strainer in the pipe line. When the motor has used 1 gallon of fuel from any tank there has been 1 gallon of air drawn into the tank through the vent. The gallon of air has carried in with it whatever water it held in suspension at the time; and air always contains a certain percentage of moisture. Everything works well until a drop in temperature condenses the moisture on the inside of the tank so that it runs down the sides into the fuel. To keep this water from making its way into the carbureter, gasoline strainers are sometimes placed at the lowest part of the gasoline pipe between the tank and the carbureter. They are of comparatively little use, however, unless cleaned out frequently.

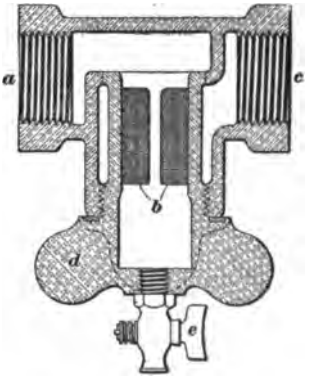

FIG. 2

37. In the strainer shown in Fig. 2, the gasoline flowing through the inlet *a* must pass through the strainer *b* and thence to the outlet *c*. Any water or moisture contained in the gasoline will adhere to the screen *b* and drop to the bottom of the strainer, from which it is ejected by opening the cock *e*. Being mounted in a screw cap *d*, the strainer may be readily removed for cleaning by unscrewing the cap.

Fig. 3 shows a strainer in which the gasoline passing through the inlet *a* flows downwards through the center tube *b* and out

into the body of the strainer by way of the holes *c*. The gasoline filters upwards through the gauze strainers *d* and passes to the carbureter through the outlet *e*. The strainer may be drained of water by opening the cock *f*.

38. It is a popular idea that gasoline and water cannot become so mixed that the water will not settle to the bottom of the vessel containing the mixture. That this is not correct, may be shown by pouring a small quantity of water in a bottle, then five or six times the amount of gasoline, and shaking the bottle vigorously for a couple of minutes when it will be seen that the water will not separate readily from the gasoline. The illustration serves also to show the importance of baffle plates in the tank to prevent the swashing and mixing going on during a seaway.

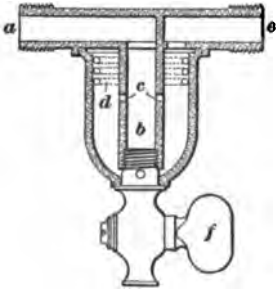

FIG. 3

A simple test for water in the fuel may be made by pouring a little on the hand, or on a piece of paper. On the hand, water will show in small globules. On paper, the gasoline will spread faster than the water and show distinctly.

CARBURETER DIFFICULTIES

39. Studying the Carbureter.—A carbureter is an instrument largely controlled by atmospheric conditions. In dry weather, less gasoline is required than in wet and less in hot weather than in cold. The reason is that gasoline, or any oil, will vaporize more readily in dry weather than in wet; or, in warm weather than in cold; hence, the use of warm-water jackets for carbureters and of the growing practice of leading warm air from the exhaust pipes to the carbureter. The purpose of these efforts is to vaporize more thoroughly the fuel with the object of rendering it more readily explosive, or faster burning.

Instead of varying the quantity of fuel it is better to vary the quantity of air, which amounts to nearly the same thing. The

admittance of more air thins the mixture and is similar to less gasoline; less air causes a richer mixture and is similar in effect to supplying more gasoline, or fuel.

40. Should anything happen to a carbureter internally, it will be necessary to take it apart; therefore, the mechanism of the carbureter should be studied. The adjustments should be learned when the motor is running well and the carbureter is in good adjustment. Every movable part should be marked and a mark put opposite on a fixed part, so that it will be readily known how much the movable part has been moved. Then one adjustable part should be moved away from and back to the fixed mark; then another part and so on until the moving of them becomes familiar. Then two should be moved at a time; then three; and so on until the entire adjustment can be upset and put back to place. This must be done at the one operation, not from one day to another, for then the meaning of the marks is not forgotten. The next trial is to remove the carbureter and take it to pieces; first having marked every movable part and having placed coinciding marks on the fixed part, in order to facilitate assembling the parts with the utmost exactness. When apart, the carbureter will show itself to be a refined vaporizer, the improvement being in matters of adjustment and control. The knowledge thus acquired will save many bills for mysterious troubles.

FIG. 4

41. Foreign Substances in Mixture.—When a carbureter is placed 2 feet or more from the cylinder, the vaporized fuel is apt to condense on the intake pipes and give trouble by being drawn into the combustion chamber in too coarse and crude a form to be readily fired. The trouble will be manifested by skipping, or by the mixture not igniting, and is more pronounced in cold weather than in warm. One remedy is to

make use of a hot-air intake. This can be easily made by enclosing a short section of the exhaust pipe with a piece of narrow stovepipe, closing the ends of the stovepipe, and tapping into it a length of piping that can be led to the carbureter.

A hot-air intake that can be adjusted to almost any style of exhaust manifold is shown in Fig. 4. The drum *a* may be attached to the manifold by the support *b* and the flexible tubing *c* can be led to the air intake of the carbureter.

In cold or moderately cold weather, the rapid cooling of the carbureter caused by the evaporation of the fuel may form ice on the inside. The effect will be the slowing down or the complete stopping of the engine. To thaw the ice wring out a cloth in hot water and wrap it around the carbureter.

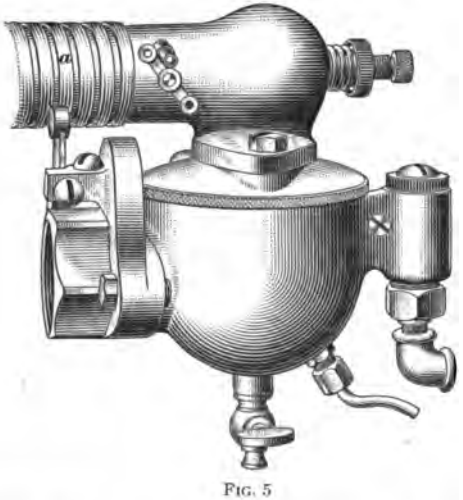

FIG. 5

42. The refrigerating process of the fuel evaporation will cause the moisture in the air to condense on the carbureter very freely at times. Without a hot-air intake, this moisture may be drawn into the carbureter by the suction of air at the intake and will either impede or stop the motor by filling the carbureter or by getting on to the sparking points when it enters the cylinders. The remedy is to wrap the carbureter in cloth, or to extend the air intake of the carbureter to a point beyond the condensation by attaching to it a piece of pipe from 8 to 12 inches long, as shown at *a*, Fig. 5.

Spray or driving rain is sometimes able to enter the carbureter even though it be protected by an extension. The only remedy for this is to throw a protecting covering over the intake.

Spray entering through portholes and reaching the carbureter may stop the motor as readily as if the engine were in the open.

43. Obstructions in Carbureter.—Fig. 6 shows that there are two places in which a very small particle of dirt will stop the operation of a carbureter. The first is at the float valve *a*, where the opening for the passage of fuel is so narrow that almost any particle of foreign matter will either plug the tube and stop the flow of fuel, or stick in the tiny circle as it tries to pass the fine point of the float valve. The result is that the point of the valve cannot seat and the carbureter is flooded by the continuous flow of fuel. The other point is at the spray nozzle *b*, where the same conditions are met as regards the size and shape of the opening, but the effect will be to reduce or stop the supply of fuel.

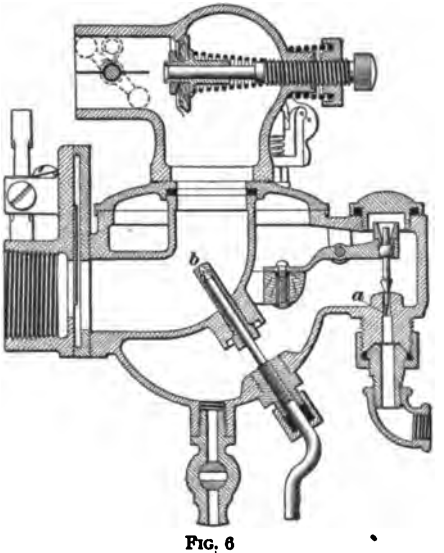

FIG. 6

The remedy, if the obstruction is in the float valve, is to press on the priming pin, thus depressing the float within and causing a rush of fuel, which may dislodge the obstruction. If the trouble is in the needle valve, it should be given three or four turns so as to loosen it, and the same rush of fuel will ensue. Should either of these operations fail, the pipe union where the gasoline enters should be removed or the needle valve unscrewed and a fine wire inserted into the float chamber in one case, and into the mixing chamber in the other, working the wire carefully around the sides. This ought to dislodge any foreign matter.

44. Another point of weakness from the exterior of the carbureter is the auxiliary air intake. The suction of air is

so great at this point that any floating or hanging material within a distance of 10 or 12 inches is liable to be drawn rapidly into the intake. The result is a gradual choking of the air and an enriching of the mixture with the attendant troubles within the cylinder.

Trouble with the auxiliary air intake sometimes arises from the weakening or strengthening of the spring by excessive manipulation, resulting in a mixture weakened by too much air, or one enriched by not having enough air. To remedy this the spring can be stretched or compressed as is required. A better remedy is to replace it.

45. Float Troubles.—Cork floats are liable to become soaked and heavy by long immersion, thereby tending to drop and let in too much fuel, flooding the carbureter. Should this occur the float should be taken out, given a thorough drying, and coated with shellac. Metal floats are subject to corrosion. When this takes place the fuel gets into the ring and makes the float too heavy, causing it to drop and flood the carbureter.

If a float happens to be set too high it acts the same as if too heavy and drops, causing flooding; the remedy is to set it lower. If set too low, the fuel will not let in enough fuel because of keeping the float valve closed. Improperly set floats, though, are seldom met for such a carbureter would not be right at any time.

VAPORIZERS

46. A frequent source of trouble with a vaporizer is that cotton waste has been drawn into the air intake, which packs in and the motor gradually slows down until it stops; in such cases, the vaporizer must be opened and cleared. Another trouble is that the air-valve springs will become weak; to stretch it out a little is the general remedy. If the spring breaks, the largest part should be taken and stretched out, as it will generally work well enough to get back to port.

The greatest trouble with vaporizers is that if they are not shut off before the switch is thrown to stop the motor there

is a bad case of flooding. When flooded from this cause, the easiest, because the quickest, remedy is to keep the gasoline supply shut off and, opening the petcocks in the cylinder, grasp the wheel and commence to crank, meanwhile leaving the switch connected; soon there will be enough gasoline thrown out of the petcocks and exhaust to allow the mixture to become nearly normal. At this stage a charge will explode and the motor will soon be running on the gasoline contained therein. As soon as it does, grasp the vaporizer and when the explosions show signs of weakening, which will be quickly, slowly turn on the gasoline, increasing the supply until the explosions sound normal. When cranking the engine during this operation, be sure that the spark is in its retarded position.

FAULTY MIXTURE

47. Testing the Mixture.—When the engine refuses to start the quickest way of ascertaining whether the mixture or the spark is at fault is to shut off the fuel supply and open the petcocks that the cylinders may be quickly relieved. Then the engine should be cranked, or turned over, a few times to be sure that the cylinders are filled with pure air only. A small teaspoonful of gasoline should be poured into each cylinder through the priming cups, or injected through the petcocks with an oil can, and after a few moments, so that the gasoline has had a chance to vaporize, the switch connected, the spark retarded, and the motor cranked. If the motor starts readily and runs until the injected fuel is used up, and then stops, it is certain that the mixture is at fault.

This being the case, look back along the pipe line for the fault. When it is located, and the motor started, the explosions may be far from proper. If the mixture was right, the explosions would be the same as when the fuel was placed directly into the cylinder. One way of determining if the mixture is right, is to watch the exhaust, which should be colorless. If it is exhausting a black smoke, the gasoline is flowing too freely for the quantity of air. Either lessen the quantity of gasoline or increase the proportion of air. If it is known that

the supply of gasoline is about right it is better to increase the air.

48. Another method of ascertaining if the mixture is right is to open one petcock and watch the color of the flame. If the flame issues red, there is too much gasoline; if it is a pale blue, the mixture is lacking in fuel. To be right, the flame must be a rich violet color. To make it perfect, the gasoline might be given in gradually increasing quantities until the flame shows a trifle of red, then reduced slowly until the red has quite disappeared and the deep violet shows clear.

An overabundance of oil will show in blue smoke from the exhaust. Excessive use of either gasoline or oil makes the running of the engine expensive.

49. At low speeds a richer mixture is required than at high speeds. With the carbureter adjusted for low speed, the air is traveling more slowly through the intake pipe than for high speed, and in cold weather some of the gasoline vapor has time to condense and settle in the pipes. The engine works very well while on slow speed, but with the change to high speed the increased velocity of the mixture through the pipe picks up the loose gasoline and carries it into the cylinder, causing the cylinder to choke and possibly to stop through flooding. The remedy for this is to start up the engine with two or three turns of the crank.

50. Too Rich a Mixture.—When the motor does not start and the spark is known to be right, the trouble may be due to too rich a mixture or to flooding. Both operate in the same way; the difference is that in the first case the vapor is not quite thick enough to precipitate gasoline, while in the second case the gasoline has not been entirely vaporized before being drawn into the cylinder.

In the case of the vaporizer, the trouble is due to the failure to shut off the vaporizer before the switch was thrown when stopping the motor; thereby leaving in the intake pipe loose gasoline, which was drawn bodily into the cylinders when the motor was started.

51. When a carbureter is used, flooding can happen only when a grain of dirt prevents the float valve closing, when the float becomes too heavy to lift far enough to close the valve, or when the float sticks and will not lift enough to close the valve. The remedy, in the event of dirt in the valve, is to shut off the gasoline at the tank, disconnect the pipe, and remove the dirt with a wire. A soaked float must be taken out, dried, then thoroughly shellacked. If the float leaks, it should be taken out and soldered. A float that sticks should be taken out and rubbed down a trifle with sandpaper; then, if it is cork, it should be shellacked.

To start a cylinder that has been flooded, shut off the gasoline, open the petcocks, connect the switch, then crank the motor. After six or eight turns, the mixture will become thin enough to explode and the engine will start. The explosions will quickly become regular. As soon as they do, turn on the gasoline. Flooding seldom happens without the operator being warned beforehand.

52. The symptoms of an overrich mixture are that the motor will start off briskly enough, then gradually slow down and, if let go, stop. In the meantime, if the exhaust is of the visible, or over-water type, black smoke will issue from it. When the slowing down begins, the supply of gasoline must be gradually reduced until the point is reached when the engine picks up in speed and sounds natural. That the carbureter adjustment was right the last time, or the last number of times, that the engine was run, is no criterion that the mixture given is correct for the present moment.

If the air is much drier, or warmer, than usual, less gasoline is required to make a perfect mixture; therefore, with the same amount of gasoline the mixture is too rich for the present state of the atmosphere. It is not the general practice to alter the mixture for the different conditions of the atmosphere, though the atmospheric conditions are often the cause of an engine running better some days than others. In this lies the benefit of becoming so familiar with the workings of the carbureter that one need not be afraid to turn the needle or the air valve

a little to the right or to the left, for the purpose of giving a trifle more fuel or a little more air.

There will often be noticed a slowing down followed by a spurting of the engine; this is generally caused by too rich a mixture and may be relieved for the moment by opening a petcock. The remedy is to lessen the supply of fuel.

53. Weak Mixture.—By *weak*, or *lean, mixture*, is meant that there is not enough gasoline in proportion to the amount of air when the two come together in the mixing chamber previous to being drawn into the cylinder by the suction of the descending piston. The reason a mixture is weak may be that there is simply too little gasoline supplied, that the air has become colder than normal, or that the air contains much more moisture than is usual, as, previous to or during rain or fog. More gasoline will be required during a cold evening following a warm day than was used in the heat of the day, because, gasoline condenses rapidly when the weather is cold. All that has condensed is useless for motive power, as it simply burns slowly. Rapidity of burning, or exploding, is the effect desired within the cylinder, and only vapor will do that. Moisture in air produces the same result in the mixture as cold. For this reason the leading of warm air from the exhaust to the carbureter is growing in favor, and deservedly so.

54. Loss of power, and back firing are the prominent symptoms of a weak mixture. The remedy is to open the gasoline needle valve, a little at a time, until the back firing ceases. If after this is done the engine begins to slow down, the slowing down will demonstrate clearly that the mixture was weak, not because of too small a supply of gasoline, but because of too much air; therefore, the needle valve must be put back to where it was and the supply of air reduced, in this way making a richer mixture.

55. Starting on poor gasoline is sometimes a hard problem, but priming the cylinders will put the motor in operation quicker than any other method. Stale gasoline is hard to start on for the same reason as caused the abandonment of carburetion by draft over a field of gasoline and by wicks; viz.,

permitting gasoline to stand allows the air to carry off the lighter portions first, and the portion left is so much heavier than the entire mixture that it will not vaporize or fire so readily.

56. Explosions in Exhaust or Muffler.—Explosions in the exhaust pipe or muffler are the result of overrich mixtures, misfiring, or a leaky valve. The whole of an overrich mixture does not always burn, with the result that it passes into the exhaust and is ready to be fired by the rush of the next charge. A misfire will send the whole charge into the exhaust, where it is liable to be fired by the next charge that is exploded. The misfired charges sometimes collect in the muffler in such a perfect state that the resulting explosion is strong enough to burst the muffler. A leaky exhaust valve sometimes lets a charge into the exhaust pipe, where it is fired by the hot gases; the remedy is to correct the valve.

BACK FIRING

57. The reasons for back firing are either that the mixture burns so slowly that fire still remains in the cylinder when the new charge enters, or, that some part is held open mechanically and allows the fire in the cylinder to escape into the intake passage.

A slow-burning mixture may be the result of too little or of too much gasoline. If the proportions of gasoline and air are changed enough the mixture will not explode or burn with great speed, but if it burns at all it will be so slowly that it is of no use for motive power. Any obstruction in the fuel supply line except in the float valve will cause a weak mixture. In the float valve it may cause either too much or too little. Too much gasoline seldom causes a back fire. Because of its slow burning, it is apt to cause the opposite to a back fire, which is an explosion in the exhaust passages. The result of a rich mixture is a carbon deposit within the cylinder, and this in time will become incandescent and cause back fires by the firing of a charge while it is entering. A retarded spark will cause back

fire at times because of the slow-burning result. Low pressure or head to the fuel supply caused either by lack of fuel, or by the vent of the tank becoming clogged, may be the cause of a weak mixture, resulting in back firing.

58. The motion of a boat in a seaway will at times interfere with the supply of gasoline and cause skipping. This is not apt to occur except in boats where the tank is located at some distance from the motor; then the incline either up or down may crowd the supply or, by suction, diminish it temporarily to the extent of either producing a change in the mixture or of stopping the engine.

The chief danger from back firing lies in the fact that because the vapor of gasoline is not seen it is presumed not to exist. No leak or drip of gasoline can take place that, when it has disappeared, has not turned into an explosive vapor, and that vapor has flowed through cracks or openings into the lowest level of the boat. It now is ready for a strong back fire to drive out through the carbureter or base and fire it. Not only is vapor found in most boats but in addition spilled gasoline or other fuel, and plenty of grease and oil; all are waiting for a back fire to start them. The providing of fire extinguishers in the form of powders, acids, salt and sand are to be commended, but care of the original drip or vapor is a much better precaution against fire. A good preventive of the back fire doing damage is to place around the carbureter a box large enough that a back fire will not burst it. This box can be made to serve another purpose as well; warm air from the exhaust may be piped to the box to aid in vaporizing the fuel.

59. The engine may run well at high speed and back fire when throttled down. At high speed, air has a much greater friction on the side of the pipes than when traveling slowly. To get enough air to preserve the balance in the mixture the air valve must be opened wider in proportion at high speed than at low: this the air valves do not do, certainly not to the extent of giving exactly the same mixture at all speeds. The result is that if perfect at high speed the mixture is too lean at low speeds through having too much air for the amount of

gasoline. This manifests itself in back firing. The remedy is to give the needle valve on the carbureter a trifling turn in the direction that will give a little more gasoline. Another way is to reduce the supply of air, although the former is the easier remedy.

Sometimes the engine runs splendidly at low speeds and is sluggish at high speed. This condition is usually caused by the engine receiving too rich a mixture at high speeds. The carbureter may be adjusted to give the correct mixture at low speeds, but does not receive enough air to form the best mixture when the engine is speeded up. The result is a slow-burning rich mixture, which causes the engine to run sluggishly. The trouble can generally be remedied by readjusting the needle valve of the carbureter, but not by opening the petcocks of the engine, as is sometimes done.

DEFECTS OF IGNITION SYSTEMS

BATTERY TROUBLES

60. A frequent cause of the quick deterioration of the dry cells in a battery is the location. If placed in a damp locker or in a cubby without air circulation dampness will collect on them and cause a short circuit. Wherever placed the cells should occasionally be exposed to the sun and any drying breeze; this strengthens them and prolongs their life.

There is also a loss of current by the lack of brightness in the connections, and the lack of firmness. Both are important factors because of the increased resistance such conditions occasion in the circuit. A person's fingers are not strong enough to properly set the binding-post nut down on to the wire, so a pair of pliers should be used, but when using them care must be taken not to twist the nut off the post.

Much trouble is created by using solid wire between the cells. Solid wire is almost always brittle and snaps easily. Stranded wire is pliable and far better for use in making connections.

61. Unless spare cells are carried, it is well before starting on a trip to test each cell in the battery with an ammeter. Cells that have been resting over night should show at least 12 or more amperes; if below that they should be discarded and new cells put in. While a cell will give service when at a lower figure than 12, it is not reliable, and one showing that figure after resting will drop considerably below it when the motor has been running 15 minutes.

Occasionally trouble is had with the spark when using the number of cells called for by the maker of the coil in use, and the trouble has been remedied by the introduction of one more cells into the battery. The addition of this cell adds to the voltage or strength of the spark, making it more snappy.

62. Chances will sometimes be taken with low testing cells and battery power will run low when not convenient. In such cases, if the distance to be run is short, drop the anchor for 10 minutes or more, at the end of which time there is likely to be a spark. Then run the motor as long as possible, drop anchor again, and repeat. If the battery is one that is connected up in multiple series, two of the rows may be connected directly in series and then connected regularly with the main circuit. In this way, the current is strengthened by the combined voltage of the two series. As many as are necessary to get a spark should be connected, but only the best cells used. Tests with an ammeter should be made on a wire from each terminal to the tongue.

Should this combination fail to produce the spark necessary the last resort is to puncture the tops of the cells and wet the contents of the interior with sal ammoniac, salt water, or fresh water; the virtue of the different liquids are of value in the order named. The whole remaining power of the cells is now brought into action.

63. To obtain the longest service from dry cells they should be packed in a box large enough to have a space below and all around the sides of each cell. This space may then be filled with dry sawdust, but it is better to pour in pitch or paraffin that is just at the molten state. The two latter sub-

stances not only preserve the cells from moisture, but render them waterproof; when protected in this manner it will be surprising what abuse they will stand; the water can be up to the wires and the motor still run.

Before buying, new cells should be tested with an ammeter and none taken that test below 21 amperes. Cells testing lower than that have deteriorated while standing.

SWITCH AND COIL TROUBLES

64. Switch Troubles.—The wire to the switch and all the primary circuit will give less trouble if made up of strands instead of a solid wire, and is kept free from oil or moisture. It must not be run in damp places or there will be short circuits because of the deterioration of the insulation.

As the switch is generally in an exposed place the connections become corroded from dampness in the form of spray, rain, or fog. Verdigris will collect and in time make it difficult for the current to get by. Frequent attention should be given it. Sometimes so much moisture from fog, rain, or spray will collect on the switch as to cause a short circuit; the remedy is to wipe it dry and cover it. Unnecessary current is used when short ends of wire are joined together, every joint causing extra resistance. When it is necessary to join wires, the ends should overlap each other 2 inches; then 1 inch of one wire coiled around the other wire and the free end of that wire coiled tightly around the first wire as shown in Fig. 7. If the joint cannot be soldered, it may be firmly wrapped with tin-foil, such as comes around tobacco or photograph film rolls, and bound with rubber tape. Such a joint is almost as good as if soldered and will remain bright for years.

FIG. 7

Whole lengths should be used for all sections, and if the outfit is to be kept in good order it is a good plan to renew the wiring each year, for the wires will get soaked through in places and lose current.

From the constant use to which it is subjected, the switch frequently becomes loose both from its fastenings and the contacts. Firm and bright contacts must be maintained to get the full strength of the current. More broken wires occur at the switch than at any other place because of the frequency of the handling at that point.

65. Coil Troubles.—Many things may happen to the coils and each are hard to detect, but one of the most common destroyers of a coil's efficiency is salt water. Often a single wetting will cause trouble because of the rust occasioned. When coils get wet with salt water it is best to get them perfectly dry at once, because rust once started is almost impossible to stop.

Another frequent cause of trouble is the breaking of the wires at the ends. Too strong a voltage will heat the insulation and dissolve it into uselessness because of its being unable to resist short-circuiting; proximity to strong heat will have the same effect. Yet coils are improved by lying all winter in a moderately warm place or by exposure to the sun. The latter is of benefit to any battery or electric machine that is used near the dampness of salt water, or fog, or the interior of boats.

Dropping a coil or the receiving by it of a blow of any kind is liable to break the insulation on the wires, or between them, or to break the wire itself and render the instrument useless. Breaks must be remedied by the maker.

66. If using a master vibrator and individual coils, the test for defects in the primary circuit is to fasten a loose wire to one terminal of the primary wiring, or battery, and after connecting the switch, touch it to either side of all connections until the fault is found.

The test for each cylinder is to connect a loose wire to one secondary terminal on the coil, then test at every connection the same as was done in the primary circuit.

The chief trouble of individual coils is that the core may offer such a high resistance through being rusted at the ends that a good spark cannot be produced. This can be known by testing the spark at the plug. Contact points that are not

smooth will reduce the spark to uselessness. If the spark cannot jump ¼ inch with a good snappy vim it is not strong enough.

MAGNETO TROUBLES

67. In a low-tension, magneto, ignition system the troubles are practically the same as in a battery system because the low-tension magneto supplies a current of low voltage the same as a battery.

The high-tension magneto performs all the functions of the generator, coil, timer, and distributor within itself, so that its defects are naturally more complicated than those of the low-tension machine. Troubles in it may originate from lack of grease in the cups, or of oil in whatever part is to be oiled. The different makes vary greatly in this respect. The brushes must be cleaned frequently with a small brush and gasoline. The timer must be kept in perfect time with the timer in the primary circuit if a separate one is used. Whenever the instrument is disconnected the teeth in the gearing must be marked so that the same teeth will touch the same as before. The springs holding the brushes in place must be watched to see that they retain their strength. The distributer will make a short circuit or a misfire if loose grains of metal from the brushes or contacts are not removed. The contacts must be kept bright and the brush springs watched for weakness. Misfiring, or slowing down, will draw attention to the brushes when they need attention. Weak magnets and armature troubles should be cared for by the maker.

68. When testing a friction-driven magneto for a weak spark, the first thing to do is to examine the primary circuit for troubles. Having set the primary circuit in order and the spark remaining weak the fault must be looked for in the high-tension circuit. First try, and make firm, all connections. Then examine the brushes to see if they are worn, the circuit-breaker to see if it is breaking properly, the bearings to see if they need oil, and, most particularly, the friction drive to see whether it is slipping because of oil or water being on the

engine wheel. If slipping is caused by water a piece of waste will dry it out; if caused by oil, the oil may be removed from both the flywheel and the friction drive by means of a piece of waste wet with gasoline. Not much gasoline should be put on the drive if it is of rubber, however, because gasoline is a solvent for rubber.

Another cause of trouble in a friction drive that will decrease the power of the machine is the wearing of the rubber. Sometimes it will chew off and at others, flatten out; in either case it is better to renew it. In other cases the magneto is not mounted so the drive will bear evenly on the flywheel and there is a loss of power.

A belt-driven magneto is subject to the same conditions; it is more reliable than the rubber friction. Especial care must be taken that the grease cups on either are kept supplied, and screwed down.

VIBRATOR ADJUSTMENT

69. When the buzz of the vibrator does not sound right, the timer, or the make-and-break contacts should be brought together until the vibrator buzzes, and the vibrator unscrewed until it ceases to buzz; then with the timer or the make-and-break contacts together, the vibrator should be slowly screwed down until it commences to buzz, checked with the set nut, and the motor started. If all cylinders receive proper explosions, the vibrator is set right. Should any of them misfire, the vibrator for that cylinder should be screwed down gently until the explosions come regularly, then the adjusting screw set. The vibrator is now adjusted to the least amount of current with which the mixture in the cylinder can be fired to advantage. Screwing the adjusting screw any tighter creates more tension and therefore a stronger resistance for the battery to overcome, hence the life of the battery is being wasted. On the other hand, too light an adjustment will give a weak spark and the power is lost.

70. There are on the market reversible vibrators that can be turned after coming in from a trip. In that way the current goes through them in the opposite direction when next

they are in use, and reverses the process of pitting by throwing off atoms from the raised side into the pitted side, leveling it again. A finer application of that principle is to be had in an instrument that reverses the current with each contact. This would reduce trouble from that source to a minimum.

The trouble occasioned by pitting comes from the raised point on one side of the vibrator making such a poor contact with the pitted surface on the other vibrator point that the electric current cannot pass through. The remedy is to file the points flat.

71. The adjusting of vibrators for different cylinders with the attending difficulties may be dispensed with by using a master vibrator. In this way the same spark is thrown into every cylinder, and as the mixture for all cylinders can be made almost alike by using but one carbureter, the explosions are alike and the force transmitted to the crank-shaft uniform. This vibrator is made in reversible form. It is a big trouble saver.

72. With the exception of the spark plug, the vibrator comes in for the greatest amount of tinkering. If of the non-reversing type, the pitting soon commences and the file comes into use. This is something that cannot be helped with that type of vibrator. The great resistance caused by the building up on one point and the pit eaten into the other reduces the efficiency of the spark until skipping begins. The vibrator contacts must be examined each time the boat starts on a trip and filed flat if the irregularity is noticeable to the eye, so that the points may come together perfectly flat. In no other way can the current pass easily. A sticking vibrator will cause a late spark, therefore a weak explosion. It will also cause irregular explosions.

A defective condenser will be quickly noticed by the sparking that will take place between the vibrator contacts. The remedy is to send the condenser to the maker to have it repaired or replaced.

TIMER AND DISTRIBUTOR TROUBLES

73. Timer Troubles.—Lack of oil on the timer will cause it to wear the shaft, gears, and contact points. The wear of the gears will make a noisy machine and an ill-timed spark. The wear of the shaft will augment the wobble caused by the wear of the gears and interfere seriously with the proper timing of the spark. If the gears show wear, it is better to have them renewed. The shaft may be bushed.

Many timers are made with a fine-toothed brass ratchet that is engaged by a steel tooth fixed in a handle controlled by a spring. The steel tooth is often blunt and the spring weak; the consequence being that the engaging tooth slips back and forth across the face of the timer teeth, thus causing the spark to be alternately advanced and retarded. One remedy is to put in a sharper engaging tooth and a stronger spring, but, as the fine teeth of the timer provide for a variation of speed that is entirely unnecessary and the liability of continued trouble is so great, it is better to substitute a new plate with coarser teeth or cut the row off entirely and file in a new set on the same plate. In the latter case a longer engaging tooth must be inserted. The placing of a spiral spring between the handles of the timer for the purpose of keeping them spread and thus pushing the engaging tooth into the ratchet is oftentimes an annoyance because of its tendency to fall out. To overcome this tendency, drill a hole through both upper and lower handle of the timer and push a brass nail through the holes and the spring.

74. Engines having the timer contact made close to the propeller shaft should be positively rejected. A slight drip of gasoline neglected will fill the bottom of a boat with vapor the same as a drip of water will fill a bowl, and as very few are careful enough to keep the boat entirely free from such vapor, with the spark so low down the danger of firing the fumes is ever present. Fire starting in this way is vastly different from firing loose gasoline for the entire boat is in flames more quickly than any one can jump overboard.

75. Timer contacts placed inside a case on top of a timing shaft are in a good position for examination and care; the most important trouble is from neglect to oil. As the timer seldom has provision for oiling except by taking off the screwed-on cap it is easily forgotten. The result is a wearing of the shaft and a scattering of iron and brass dust, which in time makes a short circuit that prevents the plugs receiving enough snappy electricity to fire the charge regularly, though the spark may be received in good form at times. The action of too much voltage on the timer contacts is to score and roughen them, causing poor contacts, therefore a poor spark. The contacts should be examined once in a while.

76. If the contact container is fastened to the timer shaft by means of a setscrew, the screw may become loosened by vibration and slip up, down, or sidewise. In any case the time of firing will be wrong and possibly there will be no sparks.

The primary wires from the timer are very apt to get soaked with oil. They should be renewed because of the insulation becoming spongy. The right teeth may not come together on the timing-shaft driving gear, thereby making the spark late. The contacts may have become roughened or pitted by too strong a spark. The setscrew can be readjusted, also the gear-teeth. The contact points must be smoothed with fine emery. They should be examined to see that they have spring power enough to make them press firmly when making the contact. If the timer shaft is out of true from the wear of either the driving gear or the shaft the defective part should be renewed or bushed.

77. Removing Timer.—When necessary to remove the timer and shaft, two teeth that come together on the driving gear at the base of timer shaft should be plainly marked. This mark must be clear and distinct, for should there be any ambiguity about it the chances are that the shaft will not go together as it came apart. At the same time note must be made what contacts come together next at the top of the timer.

78. Testing the Timer.—The timer can be tested when the rest of the primary circuit is known to be in good condition by closing the switch, then pressing the end of a spare wire to the stationary contact in the timer and the other end of the wire to the center shaft, or grounded part of the timer. If it starts the vibrator the wire should be removed and the revolving contact swung until it touches the same contact; if this moves the vibrator with the same vigor the contact is good. Try out all the timer contacts in the same way. The spark in the magneto and the timer must work at the same instant; otherwise there will be no spark. This applies in particular to a timed magneto. The friction-driven magneto generates a constant current and works the same as a battery. The timing also is to be the same for a dynamo.

79. Distributor Troubles.—A distributor is generally attached to the magneto and is geared to time with the pistons for the explosions. Nothing much can go wrong with it except as it gets dull or dirty. It must be kept bright. If taken apart for any reason, the gears should be notched so that the same teeth will go together when reassembling. One source of trouble is from the crossing of the wires on the timer or on the distributor.

SPARK-PLUG AND IGNITER TROUBLES

80. Spark plugs and igniters are often worked until they will spark no longer because of the thickness of the deposits upon them. In factories where they are used the year round, they are cleaned at regular intervals, in some cases after every 10 hours' running. The most common deposit is from excess fuel or oil, in the form of soot, and this is readily removed by a toothbrush that has been dipped in gasoline. While at it, the whole plug should be cleaned. When taking out the plug or igniter the wrench must not be applied to the nut above the one that enters the cylinder head, for the twisting of this nut is very apt to crack the insulation. It also loosens the shaft of the plug enough to permit oil to work its way in and short-circuit the current.

When a short circuit is suspected in a make-and-break igniter, the contacts must be brought together by turning the wheel, then the wire removed from the top of the firing pin and the circuit at the switch closed. When the wire is wiped across the top of the igniter, if there is a good spark, turn the wheel until the contacts are not connected, still keeping the switch closed, and then wipe the wire across the top of the pin again. If there is a spark, it shows a short circuit in the igniter, which must be taken out and examined. It will be found that either the insulation is cracked or torn, or that oil has worked its way into the insulation. Both of these happenings are likely due to the nut on the igniter having been twisted at some time when the wrench was meant to be applied to the nut holding it into the cylinder head.

81. Around the shaft of the igniter will be found a wrapping of mica or other insulating material. Above and below the shaft wrapping of mica will be found washers for insulation. These are for the purpose of protecting the plug from contact with the surrounding metal. If any of these insulations are cracked or torn the electric current will go through them in preference to taking the longer route by way of the contact points. If oil soaked, the electric current will run through the oil to the body of the motor and thence to the ground wire. All cracked insulations must be renewed.

One method of removing the oil is to put on a few drops of gasoline and fire it either by sending a spark through or with a match; repeating this two or three times will dry out the oil and any dampness. Another way is to take off the wrapping of the washers and polish them dry with a dry cloth, or waste. In putting together care must be exercised not to twist or wrench the insulations.

82. To test the jump-spark plugs for a short circuit, disconnect the wire from the plug, remove the plug from the cylinder, close the switch and turn the wheel until the contacts come nearly together. Now reconnect the wire that belongs on the plug and lay the plug on the cylinder head, then turn the timer until the contacts touch. If the plug is right the

spark will jump across the gap as it should. If there is a short circuit, the spark will leave the plug at some other point. In the latter case the cause is from broken, cracked, or oil-soaked insulation, and the remedies the same as for a make-and-break igniter. In addition the porcelain on some makes of plugs may be cracked, in which case it must be renewed.

The management of the sparking points on a jump-spark plug will have much to do with the comfort in running a motor boat. The popular idea has been to have them $\frac{1}{16}$ inch apart, or, one-fourth the distance the spark can jump. In practice it will be found that better results are obtained by placing them closer, but not too close, or there will be no fatness to the spark; it must have some resistance by the air to create the necessary heat for firing the charge. Another test is to place a piece of paper of ordinary thickness, not a stiff hard paper, between the points; if the spark is not strong enough to burn through the paper the points must be moved closer. If still not strong enough, the battery power must be increased.

83. A short circuit is often created on the outside of a spark plug by water, in the shape of rain, spray, or fog, or by the careless use of oil. In cases of this kind, short-circuiting generally can be seen by watching the plug closely when the circuit is connected. A tiny blue streak will be seen darting down the outside of the plug to the cylinder. The remedy is to dry off thoroughly any water on the plugs.

Salt-water spray leaves a deposit of salt on all that it touches. If left undisturbed, this deposit gathers on plugs, switches, and wires, and on damp days it collects moisture from the air and bridges over the gaps between terminals of all sorts. Even though it does not create a decided short circuit it will bring about a steady leakage of current. Fog will do the same thing. The remedy is to keep all such places dry by wiping or covering them.

84. Water is oftentimes introduced to the spark points by way of the entering mixture, having come from the tank or been drawn in through the carbureter in the form of spray,

fine rain, or the congealed moisture on the outside shell. Dampness does not do this. Water is also brought into the cylinder by the way of leaking gaskets on cylinder heads. The remedy for the former troubles is to have a strainer in the pipe line between the carbureter and tank, or to cover the carbureter so that spray or rain cannot enter it. The remedy for absorbing water from the air by having it condense on the carbureter has been given. The remedy for water from the water-jacket leaking through the gasket is to put on a new gasket. To insure good running, spark plugs should be cleaned after every 10 hours of running.

85. In the make-and-break system, the break of the spark is accomplished by a trip attached to a shaft that is operated by the propeller shaft. The trip has a spring that is so liable to get out of order and be useless that many carry one or two extra. Should the trip spring get out of order and no duplicate be had at the time, the engine is not rendered useless. The trip can be held in position with a piece of wood properly arranged.

86. The end of a make-and-break firing pin wears rapidly through the action of the spark, and the part with which the pin makes the contact will pit, sometimes to such a degree that the firing pin sticks in the hole. To lessen the trouble of frequent adjustment the bottom contact may have a small piece of hard metal embedded in it. The point of the pin can be treated in the same manner, but this is unnecessary expense. The firing pin is made long and it is an easy matter to file the corrosion off it with a medium-fine file. The taking out of the pin and setting it in is the work of only a few minutes.

The shaft operating the firing pin will let exploded gas through the opening by which it enters the cylinder unless the fit is perfect. In time, the gas will deposit so much carbon on the firing shaft that it will stick on the up-stroke and refuse to come down. Oftentimes a little kerosene can be worked into the passage and by frequent wipings as the pin is twisted back and forth the carbon can be washed out. If this cannot be done the shaft must be removed, cleaned, and oiled.

Occurrences of this trouble repeated many times indicate the need of a new pin or perhaps a bushing.

The spacing of a make-and-break contact is regulated by releasing the set nut and adjusting the firing pin to $\frac{1}{8}$-inch play. Many types of make-and-break firing systems have the sparking device and contact all in one setting, which can be taken out of the cylinder by the taking off of a few bolts. While this is convenient, it is conducive to loss of compression, because the gasket is easily destroyed. The operator must always be careful in removing the bolts and lifting out the mechanism. The firing pin of a make-and-break engine must be reset after each filing.

87. Since the introduction of the combined spark coil and plug, the jump spark has grown rapidly in favor, particularly in open boats or where the motor is exposed to the weather. In this combination, no secondary wire is exposed, for the whole secondary circuit is contained within the one structure; as a result the jump spark is superior to and will stand more hard usage than the make-and-break. It also requires less attention.

Some coils are made with the coil, condenser, vibrator, and spark plug in one piece. Other makes have the coil and plug in one piece, the vibrator and condenser being contained in a separate waterproof box. In this instrument the vibrator is sometimes reversible, thereby saving the troubles that arise from pitting. It is also a master vibrator and ideal in its operation for two or more cylinders. To adjust the vibrator in this instrument proceed as already directed. After that is done and as many revolutions are obtained from the engine as the maker credits it with, a mark should be put on the adjusting screw, preferably at its top, with a file. Then, the fingering of the curious, or the result of one's own carelessness will not be a serious inconvenience, for the screw can be returned to its proper position without guessing. This does not mean that one adjustment is good for all conditions, but it does mean that with a reversing vibrator such as is commonly in this box, and a proper care and testing of dry cells, or the use of a magneto kept in order, the vibrator need not be touched in weeks

or perhaps months. If reversible it must be reversed end for end before starting out on each trip.

88. When trying a combined coil and spark plug for short circuit, take out the plug and reconnect the primary wires to it, then send a spark through it. If the spark jumps the points the plug is right; if it does not, the porcelain on the plug is cracked and must be replaced. There is not much chance of these plugs becoming short-circuited by oil, but the cracking of porcelain is fairly frequent.

WIRING DEFECTS

89. The wire from the jump-spark coil to the spark plug is hard to control and must have good care. One cause of trouble is lack of care in keeping oil from it. Nothing will rot rubber more surely than oil. When the decay has worked in deep enough the high tension of the current necessary for a jump spark goes through easily and jumps to anything within reach. The current may be depended on to take the easiest way back to its source that can be found.

When making connections with the secondary wire all ends should be as short as possible and covered with a cap or with tape. A little oil on the heaviest insulation will weaken the retaining power of a secondary wire. Water on the wire is not much less damaging. To reduce the escape of the current from these causes it is well to coat the insulation with shellac. Another good plan is to draw over the wire a pure rubber tube, which makes it as near electric-proof as it can be.

Coming into contact with the exhaust pipe destroys insulation almost instantly. Resting against the hot water-jacket has a bad effect. Winding rubber tape thickly around such wounds will make a good repair. The two secondary wires should not be allowed to come into contact; in fact, they should be separated an inch or more for safety. Neither should they be allowed in contact with any metal. Fog will form a short circuit for the spark between weak insulation to any conductor; water will do the same. To have the greatest comfort

obtainable with high-tension, or secondary, wires the coil should be placed as near the spark plug as possible.

Solid wire has the disadvantage of being brittle and easily broken. However, connections are made more easily with it. At the same time, it obliges one to make connections more frequently because of the ease with which it parts at binding posts or clamps of any kind. It also parts easily when struck, or trodden upon, often without puncturing the insulation, and such breaks are hard to find.

TESTING THE IGNITION SYSTEM

90. Testing Make-and-Break System.—A long wire, the same size as that in the circuit, should be kept for testing the ignition system. When making this test, attach the wire to the ground end of the battery and close the switch, and then bring the flywheel up until the electrodes or contact points within the cylinder, are together. The supposition is that there has been no spark; if there is a spark, the points must not remain in contact all the time the circuit is being tested for this would run down the battery. Now connect the long piece of spare wire to the battery terminal that holds the end of the ground wire from the engine. Commence the test by wiping the loose end of the spare wire across the end of the wire from the battery to a bolt on the engine on the battery side of the bolt. If a spark is obtained, the fault is in that stretch of wire. The fault may be a wire broken within the insulation, or a torn insulation, or it is water- or oil-soaked and resting against some damp spot, or a tool, or anything that can conduct electricity, in which cases the insulation gives no protection and the current will leave the wire for any path that offers less resistance. If no fault of this kind is found the wire may be examined for a break as already explained. A broken wire should not be mended, for every joint and connection add to the resistance to the flow of the electric current around the circuit. Resistance cuts down the battery energy and adds to the difficulty in getting a good spark; therefore, only whole lengths should be used from one connection to the next.

91. Having corrected any fault that existed in that length of wire, the same process can be applied to all lengths of wire. The next proceeding is to wipe the free end of the spare wire across the other side of the bolt on any part of the engine. There is often so much dirt around this bolt that it is hard for the current to get through it to the wire; if such is the case, thoroughly clean about the bolt. The end of the spare wire should then be wiped across the top of the igniter, when a good spark should result because the contacts are connected. If there is not, the igniter must be taken out and the point of the movable electrode cleaned; the fixed electrode within the cylinder must also be examined to learn if it is scaled or pitted. This can be done by inserting a file through the plug hole and scraping the electrode; if it is found to be in bad shape, the cylinder head must be taken off if it is removable.

In this test the spark may have gone through all right in the first trial yet have been by the way of a short circuit instead of through the spark points. This is determined by throwing the points out of contact and wiping the end of the wire across again, and obtaining just as good a spark. It is now established that a short circuit exists in the igniter. The fault will generally be found in the insulation that is around the shaft of the igniter or in the insulating washers, which may be cracked, broken, or oil soaked. If the latter, the oil may be burned off by putting a few drops of gasoline on the oil and firing the gasoline either with a match or by a spark. Another method is to take off the insulation and clean it with a piece of waste, then wrap it about the firing-pin shaft again.

92. The tearing or cracking of insulation on the plugs is mostly done when the igniter is taken out, the wrench being placed on the wrong nut and a twist or two given before the mistake is discovered. If the fault is in a cracked or torn insulation, the short circuit can, in most cases, be temporarily repaired by readjusting the washers or shaft wrapping so that the breaks will not come opposite one another. The best remedy for short-circuited igniters is to have a spare one on hand and insert it. Each cylinder can be tried in the same

manner. The shocks received from these wires can be avoided by using rubber gloves, or finger tips; or by picking the wires up with a bunch of cotton waste in the hand. When going along from one connection to another the wire at each should be pulled to see if the grip is solid; when making connections, the strength of the fingers should not be depended on, though too much force must not be applied to the pliers.

The end of the spare wire should next be wiped across the connection on the coil nearest the igniter. If a good spark is not produced and the fault is in the coil, this may be determined by wiping the end of the wire across the coil terminal nearest the battery; a resulting good spark shows that the fault is in the coil. In that case the wire connections should be examined. If none are found broken, it is well to assume that a wire has been broken or that the insulation has been pierced on the inside. The coil should in that case be sent to the maker.

93. Both sides of the switch should now be tried. If the spark is not good through the switch, the wires should be disconnected and the ends scraped to a bright finish; the switch must then be cleaned and all verdigris and crusted salt removed. With the switch cared for and the wire from it to the battery tested, the wire should be wiped across the terminal of battery nearest the switch. No spark, or a poor one at this point calls for first a pull at each connection, then a glance to see whether any tool or wire is making a short circuit, or if any of the cells are damp on the outside. All these being right, a test of the cells with an ammeter will show if all the cells are up to the standard. Should there be no ammeter a good test can be had by connecting a wire to each pole of a cell and placing the ends on the tongue. No harm can be done by the power contained in a single cell. The difference between a strong current and a weak one can readily be distinguished. A cell must never be short-circuited for more than an instant at a time as the strength is taken from them too fast.

94. Testing a Jump-Spark System.—The primary circuit of a jump-spark system may be tested in about the same manner as the make-and-break system. The vibrator should

be examined for pitting or sticking and readjusted by turning the readjusting screw back until the points will not vibrate, then screwing it down until the points do vibrate, after which it may be made right by turning a trifle further.

A short circuit will be disclosed in the primary line by disconnecting the wire running to the switch and wiping it across the switch with the switch connected, at the same time having the contacts in the timer out of contact, or the contacts in a make-and-break out of contact. If there is a short circuit the wiping of the wire across the switch will give a spark. An ammeter inserted between the end of the wire and the switch will show if there is any current running. The short circuit may be caused by fog, salt water, rain, or tools lying on two wires. Everything must be wiped dry.

If the cause of the weak spark has not been found in the primary circuit, the secondary, or high-tension, circuit should be overhauled.

95. Assume the spark plug has already been tested and been found to be free from soot; that the points are the right distance apart, and no short circuit in it, the spark being able to jump the gap between the points, but not with sufficient strength. First, it is necessary to see that all connections are firm. The insulation must then be examined to see that it is not burned through from contact with exhaust pipes, or weakened by contact with the cylinders. Neither should it be oil- or water-soaked. Any of these defects may, if near any metal, allow the high voltage of the current to go through the weakened insulation and find an easier path with less resistance.

The secondary wire must be examined for sharp bends or breaks, all of which must be eliminated. The short wires at the end of the coil may be broken yet stay together, or too strong a voltage may have been sent through the coil and enabled the current to pierce the interior insulation; the coil may have received a blow that has severed a wire in the windings; rust may have worked its way into the soft iron wires of the core. Any of these will weaken or destroy the efficiency of the coil; the best way is to have it fixed by the maker.

In all tests of the secondary circuit, rubber gloves should be worn or the wire held with a good bunch of perfectly dry cotton waste in the hand. Shocks from the secondary current are severe.

96. When a misfiring is heard in a multiple-cylinder engine, as, for example, a four-cylinder engine, the cylinder in which it is taking place may be located by holding down the vibrators, three at a time. With the engine running slowly and the clutch out, hold down vibrators numbers *2*, *3*, and *4*; then numbers *3*, *4*, and *1*; then numbers *4*, *1*, and *2*; and finally numbers *1*, *2*, and *3*. If one cylinder is found that will not run the engine, the plug when taken out will be found to be short-circuited or foul. If it has wet soot on it there has been too much oil given the cylinder. If dry soot is found on it there has been too much gasoline. If the points are clean, the plug should be placed on the top of the cylinder with the metal part touching the cylinder and a spark sent through it; if the spark does not jump from point to point the plug has a short circuit. Take it apart and examine for oil or for broken insulation. Put in a new plug or wipe off and change the position of the insulation on this one.

Instead of holding down the vibrators, the wires leading to the spark plugs may be disconnected, three at a time. The plug that fails to run the engine alone, is the one in which the trouble exists.

97. Another method of controlling the vibrators when making this test is to slip pieces of cardboard or thick paper between the points of those not to be tested.

If all cylinders fire, it shows that the trouble is in some other part. In holding the vibrators down do it carefully and with the fingers; be sure not to use metal. The points should be cleaned with a small brush and gasoline; scraping with a knife makes them good soot collectors. The plug must be put back tight to avoid loss of compression.

Everything having been found in good order in the cylinders, the battery, or magneto, should be tried. These being good, the vibrator should be tested to see whether it has become pitted.

All contacts and connections must be bright, tight, and clean. The vibrator points are to be $\frac{1}{32}$ inch apart, or, adjusted as previously described. The tension must be so that there will be a good spark at the spark plugs but none between the vibrator points. If the battery terminals are corroded they must be cleaned with ammonia.

MOTOR-BOAT NAVIGATION
(PART 1)

NAVIGATIONAL INSTRUMENTS

MARINER'S COMPASS

GENERAL DESCRIPTION

1. The principal instruments used in the navigation of any type of vessel, power craft included, are the compass, the lead, the log, and the chart. The **compass** shows the direction in which the boat is going, the **lead** tells the depth of water, the **log** measures the speed and distance run, and the **chart** represents the locality in which the boat is navigating.

2. The **mariner's compass** is an instrument in which the remarkable property of the magnetic needle is utilized. This property is well known and need not be explained here in detail. It is sufficient to say that when a magnetized needle is suspended at its center of gravity it will assume a direction pointing toward north and south. In its simple form, the compass consists of a needle attached to the under side of a very light circular card, the circumference of which is graduated into a certain number of equal divisions. This card *a b*, Fig. 1, being fitted in its center with a conical

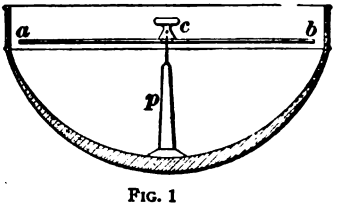

FIG. 1

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brass socket *c*, called the *cap*, is delicately balanced on a central pivot *p* around which it is free to move in a horizontal plane. By this arrangement, the card will partake of the motion of the magnetic needle and maintain a position in accordance with its directive power. The pivot on which the card rests is affixed to the bottom of a non-metallic vessel, the *bowl*, which is hung in gimbals so as to preserve the horizontal

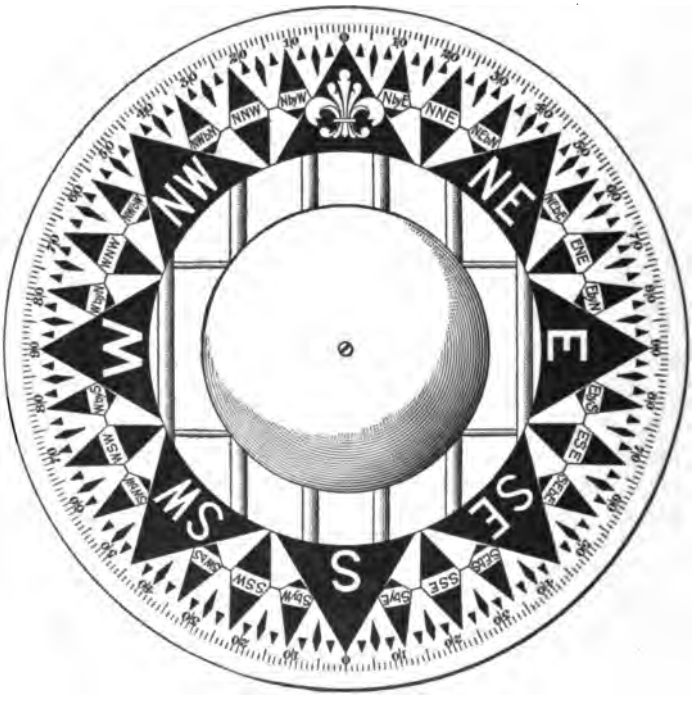


FIG. 2

position of the card, notwithstanding the rolling and pitching motions of the ship when at sea. This bowl is placed in the top of a strong cylindrical case of wood or bronze called a *binnacle*, or it is placed in a small wooden box of sufficient size to hold the instrument, as shown in Fig. 4. The binnacle is a permanent fixture used mostly on good-sized yachts and large vessels generally. The compass card with one single needle is

the simplest form used. At the present time, instead of a single needle, several are used in order to increase the directive power of the compass; and, for the purpose of reducing the friction on the pivot due to the weight of the card and needles, the card in a certain class of compasses is almost submerged in liquid.

3. As already stated the **compass card,** a representation of one form of which is shown in Fig. 2, is divided at its circum-

FIG. 3

ference into degrees arranged in four equal divisions of 90° each commencing at the north and south points, as shown in the figure. It is also divided into thirty-two divisions of 11° 15′ each, called **points.** The four principal points are named after the principal horizon points—north, east, south, and west—and are usually termed the *cardinal points*, while the points midway

between the cardinal—that is, northeast, southeast, southwest, and northwest—are called the *intercardinal*, or *quadrantal*, *points*. The names of these points should be so well fixed in the mind that they may be readily repeated in regular order from north around by way of east or west and back to north. The process of naming the points and fractional parts of points of the compass in the order they appear on the card and of naming the points diametrically opposite any given point is commonly known as *boxing the compass*.

4. Compass Points.—Commencing from the north at the top of the card, Fig. 2, and going to the right, or in the direction in which the hands of a watch move, the names of the points are shown in Fig. 2. From this, it can be seen that the cardinal points are eight points apart and four points away from the nearest quadrantal points. The name of the opposite point to any given point is known at once by simply reversing the names or the letters that indicate the name of the given point. Thus, the opposite point of N E by E is S W by W, that of N N W is S S E, that of E by S is W by N, and so on.

5. The space between each point is divided into four equal parts, called *half* and *quarter points*. Thus, the expression N $\frac{1}{4}$ W means "north a quarter point to the west," and S E by E $\frac{3}{4}$ E means "southeast-by-east three-quarters of a point to the east." There is no particular system in expressing half and quarter points, but experience has taught that the simplest is the best. Hence, the expression N N E $\frac{1}{4}$ E is preferable to N E by N $\frac{3}{4}$ N, although they both indicate the same point; and likewise, N by E $\frac{1}{2}$ E is preferable to N N E $\frac{1}{2}$ N. Absurdities like W by N $\frac{1}{4}$ W and N by E $\frac{3}{4}$ N should never be used. The system given in Table I is the one that should be followed.

6. Comparison of Old and New Cards.—In the old compass card, shown in Fig. 2, the graduation by degrees begins at north and south and runs 90° to right and left toward east and west. In the new form of compass card, adopted by the U. S. Navy department, the degrees run in a continuous graduation to the right from north to north again, through 360°, as shown in Fig. 3. This card, however, retains the divisions of thirty-two

TABLE I

CONVERSION OF COMPASS POINTS INTO CORRESPONDING READINGS OF THE NEW COMPASS CARD

Compass Points	New Card	Compass Points	New Card
N ¼ E	2° 48′ 45″	E by S	101° 15′ 0″
N ½ E	5° 37′ 30″	E S E ¾ E	104° 3′ 45″
N ¾ E	8° 26′ 15″	E S E ½ E	106° 52′ 30″
N by E	11° 15′ 0″	E S E ¼ E	109° 41′ 15″
N by E ¼ E	14° 3′ 45″	E S E	112° 30′ 0″
N by E ½ E	16° 52′ 30″	S E by E ¾ E	115° 18′ 45″
N by E ¾ E	19° 41′ 15″	S E by E ½ E	118° 7′ 30″
N N E	22° 30′ 0″	S E by E ¼ E	120° 56′ 15″
N N E ¼ E	25° 18′ 45″	S E by E	123° 45′ 0″
N N E ½ E	28° 7′ 30″	S E ¾ E	126° 33′ 45″
N N E ¾ E	30° 56′ 15″	S E ½ E	129° 22′ 30″
N E by N	33° 45′ 0″	S E ¼ E	132° 11′ 15″
N E ¾ N	36° 33′ 45″	S E	135° 0′ 0″
N E ½ N	39° 22′ 30″	S E ¼ S	137° 48′ 45″
N E ¼ N	42° 11′ 15″	S E ½ S	140° 37′ 30″
N E	45° 0′ 0″	S E ¾ S	143° 26′ 15″
N E ¼ E	47° 48′ 45″	S E by S	146° 15′ 0″
N E ½ E	50° 37′ 30″	S S E ¾ E	149° 3′ 45″
N E ¾ E	53° 26′ 15″	S S E ½ E	151° 52′ 30″
N E by E	56° 15′ 0″	S S E ¼ E	154° 41′ 15″
N E by E ¼ E	59° 3′ 45″	S S E	157° 30′ 0″
N E by E ½ E	61° 52′ 30″	S by E ¾ E	160° 18′ 45″
N E by E ¾ E	64° 41′ 15″	S by E ½ E	163° 7′ 30″
E N E	67° 30′ 0″	S by E ¼ E	165° 56′ 15″
E N E ¼ E	70° 18′ 45″	S by E	168° 45′ 0″
E N E ½ E	73° 7′ 30″	S ¾ E	171° 33′ 45″
E N E ¾ E	75° 56′ 15″	S ½ E	174° 22′ 30″
E by N	78° 45′ 0″	S ¼ E	177° 11′ 15″
E ¾ N	81° 33′ 45″	South	180° 0′ 0″
E ½ N	84° 22′ 30″	S ¼ W	182° 48′ 45″
E ¼ N	87° 11′ 15″	S ½ W	185° 37′ 30″
East	90° 0′ 0″	S ¾ W	188° 26′ 15″
E ¼ S	92° 48′ 45″	S by W	191° 15′ 0″
E ½ S	95° 37′ 30″	S by W ¼ W	194° 3′ 45″
E ¾ S	98° 26′ 15″	S by W ½ W	196° 52′ 30″

TABLE I—*(Continued)*

Compass Points	New Card	Compass Points	New Card
S by W ¾ W	199° 41′ 15″	W by N	281° 15′ 0″
S S W	202° 30′ 0″	W N W ¾ W	284° 3′ 45″
S S W ¼ W	205° 18′ 45″	W N W ½ W	286° 52′ 30″
S S W ½ W	208° 7′ 30″	W N W ¼ W	289° 41′ 15″
S S W ¾ W	210° 56′ 15″	W N W	292° 30′ 0″
S W by S	213° 45′ 0″	N W by W ¾ W	295° 18′ 45″
S W ¾ S	216° 33′ 45″	N W by W ½ W	298° 7′ 30″
S W ½ S	219° 22′ 30″	N W by W ¼ W	300° 56′ 15″
S W ¼ S	222° 11′ 15″	N W by W	303° 45′ 0″
S W	225° 0′ 0″	N W ¾ W	306° 33′ 45″
S W ¼ W	227° 48′ 45″	N W ½ W	309° 22′ 30″
S W ½ W	230° 37′ 30″	N W ¼ W	312° 11′ 15″
S W ¾ W	233° 26′ 15″	N W	315° 0′ 0″
S W by W	236° 15′ 0″	N W ¼ N	317° 48′ 45″
S W by W ¼ W	239° 3′ 45″	N W ½ N	320° 37′ 30″
S W by W ½ W	241° 52′ 30″	N W ¾ N	323° 26′ 15″
S W by W ¾ W	244° 41′ 15″	N W by N	326° 15′ 0″
W S W	247° 30′ 0″	N N W ¾ W	329° 3′ 45″
W S W ¼ W	250° 18′ 45″	N N W ½ W	331° 52′ 30″
W S W ½ W	253° 7′ 30″	N N W ¼ W	334° 41′ 15″
W S W ¾ W	255° 56′ 15″	N N W	337° 30′ 0″
W by S	258° 45′ 0″	N by W ¾ W	340° 18′ 45″
W ¾ S	261° 33′ 45″	N by W ½ W	343° 7′ 30″
W ½ S	264° 22′ 30″	N by W ¼ W	345° 56′ 15″
W ¼ S	267° 11′ 15″	N by W	348° 45′ 0″
West	270° 0′ 0″	N ¾ W	351° 33′ 45″
W ¼ N	272° 48′ 45″	N ½ W	354° 22′ 30″
W ½ N	275° 37′ 30″	N ¼ W	357° 11′ 15″
W ¾ N	278° 26′ 15″	North	360° 0′ 0″

points, together with the half points, and quarter points and in this respect is marked the same as the old card. With the new card, bearings and courses may be designated simply by giving the number of degrees from north. Thus, N E is 45°, east is 90°, south is 180°, S W by W is 236° 15′, N W is 315°, N by W is 348° 45′, and so on, as indicated in Table I.

7. On the old compass card, the designation of bearings and courses in degrees is governed by the graduations of that

card. Thus, N E is N 45° E and east may be either N 90° E or S 90° E; E N E is N 67° 30′ E and E S E is S 67° 30′ E; S S E ¾ E is S 30° 56′ E; S W by S is S 33° 45′ W and so on.

A comparison of the two cards shows a marked simplicity in the use of the new card. At the present time, however, many navigators and yachtsmen prefer to name courses and bearings according to the old card, and it is a matter of conjecture if the old-fashioned compass points will ever be discarded. In naming the direction of winds and currents, the system of points is likely to be retained.

8. Types of Compasses.—The types of compasses in general use are the *liquid* and the *dry compass*. Of these types, the liquid compass is the best suited for smaller craft as it is not affected so much by the motions of the boat as is the dry compass. The distinctive feature of the liquid compass is that the card with the attached needle, or needles, is submerged in a liquid composed of about 45 per cent. of pure alcohol and 55 per cent. of distilled water. The liquid is contained in the bowl, the top of which is hermetically sealed. By this arrangement, almost the entire weight of card and needles is supported by the liquid, thus reducing the friction and the wear on the pivot to a very small amount and increasing the sensitiveness of the compass. In the dry compass, the card is evenly balanced on the pivot, which supports the combined weight of card and needles.

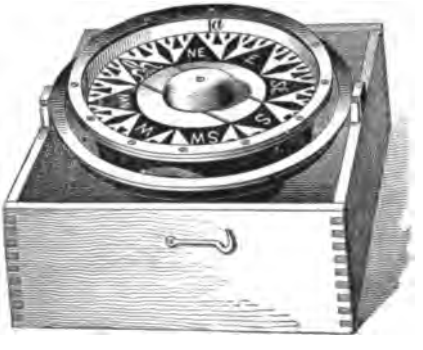


FIG. 4

9. Lubber Line.—On the inside of the compass bowl is a narrow vertical line *a*, Fig. 4, called the **lubber line**, or **lubber's point.** This line, when the compass is properly placed, will show the heading of the ship. Usually two lubber lines are drawn on the inner surface of the bowl diametrically

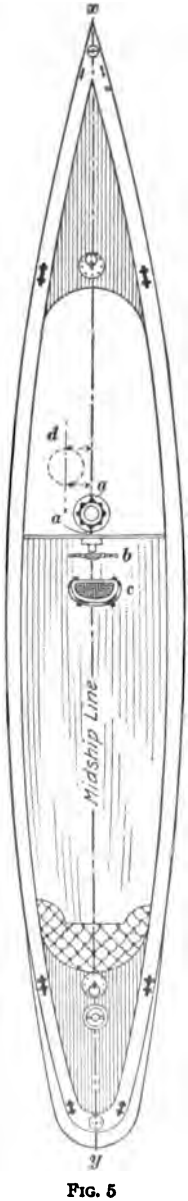


FIG. 5

opposite each other. When the compass is placed in position, these lines should coincide or be exactly parallel with the ship's fore-and-aft line. When steering, the forward lubber line is held in coincidence with the point of the card indicating the course to be run. Thus, in Fig. 4, if the lubber lines are on the fore-and-aft midship line, the heading of the vessel is N E ½ E, or, the vessel is running a N E ½ E course.

10. Compass Installation.—When installing a compass, care must be taken in the adjustment of the lubber lines so that they coincide exactly with the line of the keel, or the boat's midship line. The compass, or binnacle containing the compass, is placed in front of the steering wheel *b*, Fig. 5, in a position that leaves the compass card in plain view of the wheelsman at *c*. The center of the card and the lubber lines *a* and *a'* must be placed on the midship line *x y*, as shown in the figure. Then the point on the card that is in line with the forward lubber point *a* is said to be the direction of the ship's head, or, if the vessel is moving, its compass course. Provided the compass is properly installed and the instrument is sensitive, the slightest movement of the bow to either right or left may be noticed at once by the wheelsman by the motion of the lubber lines in relation to the compass points.

In case the compass cannot be placed on the fore-and-aft midship line, care must be taken to have the lubber marks placed on a line parallel to that line. In other words, it must be seen that the lubber lines are at an equal distance from the midship line before

the box or binnacle holding the compass is permanently fastened, as shown at *d*, Fig. 5, where the dotted circle represents a compass not on the midship line.

ERRORS OF THE COMPASS

11. Cause of Errors.—The compass may be affected by three distinct kinds of errors known, respectively, as *variation*, *deviation*, and *local attraction*. Of these, variation is caused by the magnetism of the earth; deviation, by the magnetism of the iron and steel of which the vessel is built; and local attraction, by some temporary magnetic influence in close proximity to the compass. In wooden vessels the error due to deviation is usually small unless caused by engine or iron fittings.

12. Variation.—The earth itself is a huge magnet having two magnetic poles, one situated in the northern and the other in the southern hemisphere. The magnetic needle points to these poles according to the law of magnetic attraction and repulsion. But as the magnetic poles do not coincide with the geographic, or true, poles, of the earth the needle is deflected from the true meridian. This deflection from the true north-and-south line is known as **variation.**

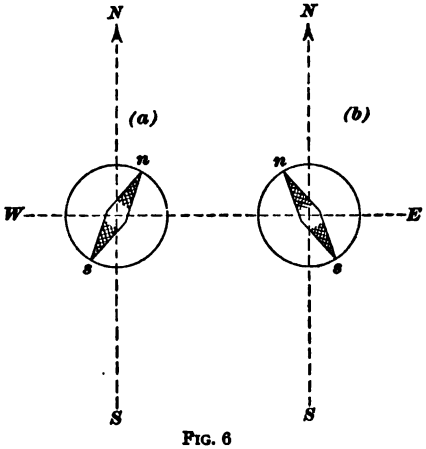


FIG. 6

Variation is so many degrees west or east, depending on the direction in which the needle is deflected. Thus, if the north point *n* of the compass needle is deflected to the east of the true meridian *N S*, as in Fig. 6 (*a*), the variation is easterly; if deflected to the west, as in (*b*), the variation is westerly. The amount of variation for any particular locality is recorded on charts and is therefore readily allowed for when shaping the

course to steer. It should be remembered that this variation is not affected by the direction in which the boat may head.

13. Change in Variation.—While the magnetic variation for any one locality is not constant, the change is so small as to be

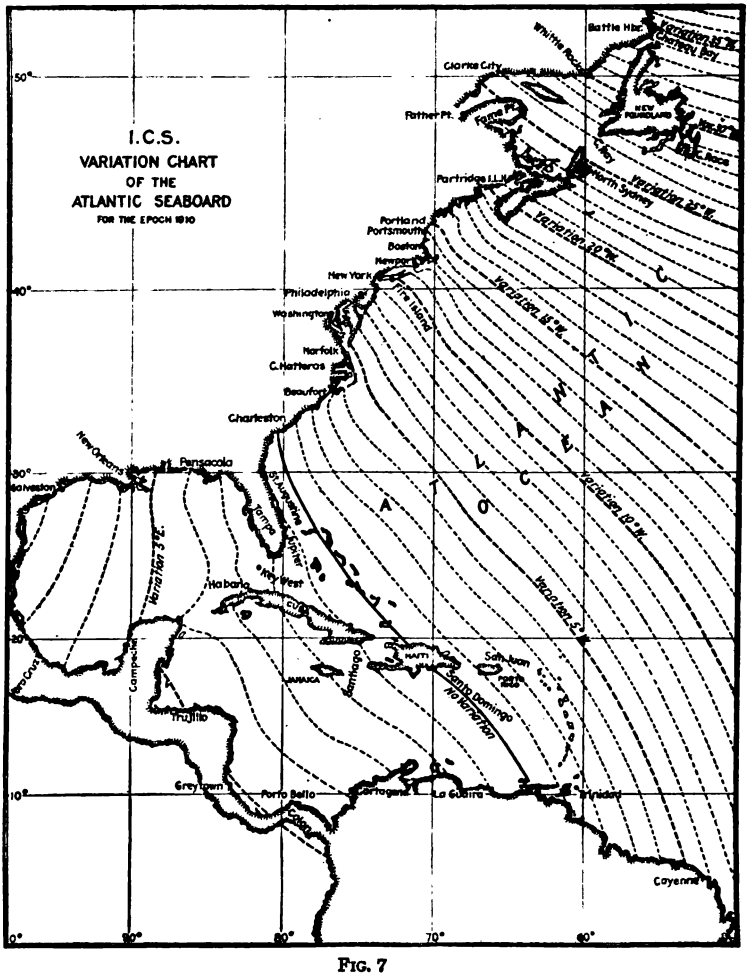


FIG. 7

barely appreciable from year to year and when once determined and registered for any place it will, with slight modification for

its annual change, serve for a considerable period. It is well to bear in mind that when the compass is influenced only by variation, such as when placed on a wharf away from iron and steel, its north-and-south line indicates the magnetic meridian at that place. This line, if extended, will cross the magnetic poles of the earth. At some places on the earth's surface there is no variation at all and by connecting such places a *line of no variation* is created.

14. The magnetic variation along the Atlantic and Pacific seaboards of the United States is shown on the variation charts, Figs. 7 and 8. On these charts, the fine dotted lines that are 1° apart indicate equal variation; that is, the variation in the space bounded by adjoining lines changes just 1°. For the sake of clearness, every fifth degree (of variation) is marked by a somewhat heavier dotted line. The line of no variation, which is plainly shown in the chart, Fig. 7, passes through Haiti and the Bahama Islands, running in a N N W direction until it enters the continent in the vicinity of Savannah, Georgia. Further inspection of this chart shows that the variation at Cape Henry is about 5° W, at Delaware Bay 7° W, at Portland, Maine, 15° W, at Cape Sable 19° W, and at Cape Race about 28° W, increasing gradually toward the north. To the west of Savannah, variation is easterly. In that part of the Mexican Gulf situated to the west of New Orleans, the variation is easterly, slowly increasing toward the coast of Mexico. At Pensacola, Florida, it is about 4.5° E, and at Galveston about 7.5° E. All along the Pacific Coast the variation is easterly, increasing toward the north. At Santa Cruz, it is about 16° E, at Seattle 23° E, and at Sitka, Alaska, about 29° E. In the vicinity of Honolulu, Hawaiian Islands, the variation is between 10° and 11° E.

15. Deviation.—As previously stated, the *deviation* of the compass is caused by the magnetism of the iron and steel in the vessel itself. This error is far more serious than variation, because it changes with the heading of the ship. In other words, if the deflection of the needle, due to iron and steel, is 10° W when the ship is heading N W the deflection may be

15° W when the bow is turned to west as shown in Fig. 9, or, the deviation may be several degrees westerly on one heading and easterly on a different heading. This is due entirely to the position of the compass in relation to the iron and steel of the ship. Thus, in Fig. 9, suppose that *a* represents an engine, or

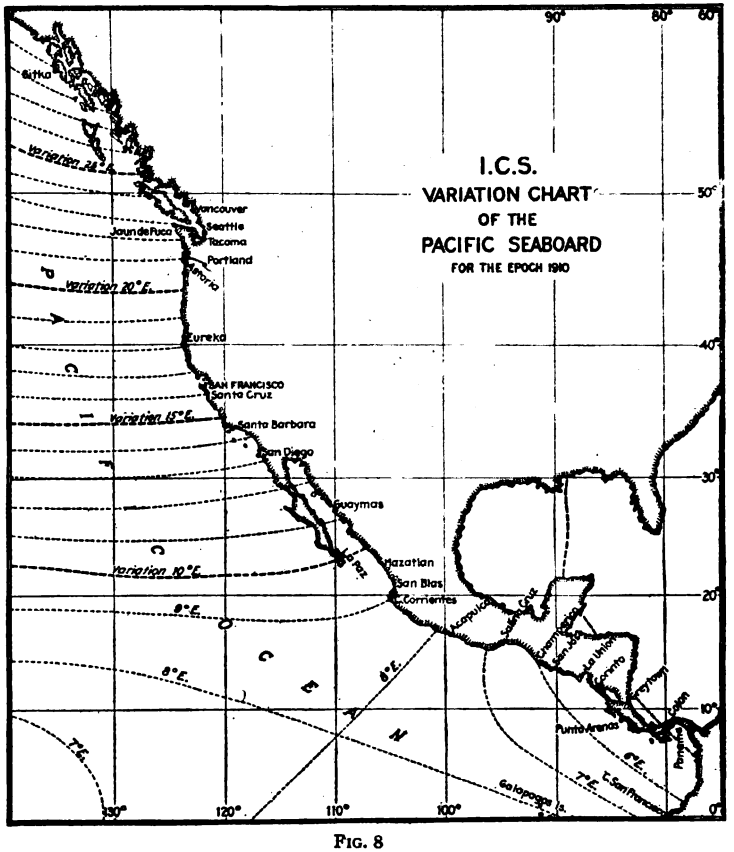


FIG. 8

other large mass of iron, located in the forward part of the vessel. This mass of iron will attract the compass needle, but its effect will be different for different headings. When the ship is heading magnetic north, for example, the disturbing force *a* will act in the same direction as the directive force of the

magnetic needle and the deflection on that heading will be a minimum. When the ship is heading northwest, as shown in the center diagram, the disturbing force *a* will act at an angle and cause a deflection. When the ship is heading west, as in the left-hand diagram, the deflection, or deviation, of the compass will be at its maximum, because in this position the

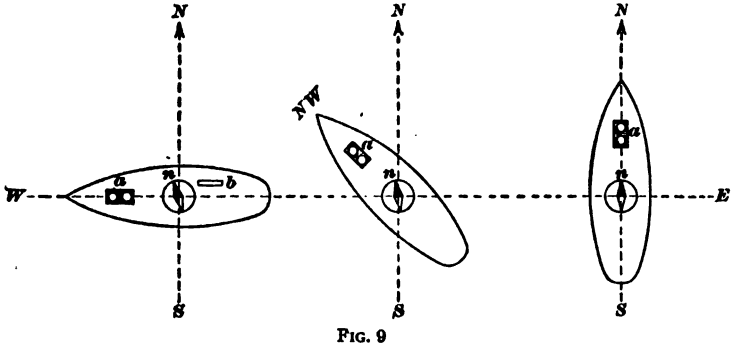
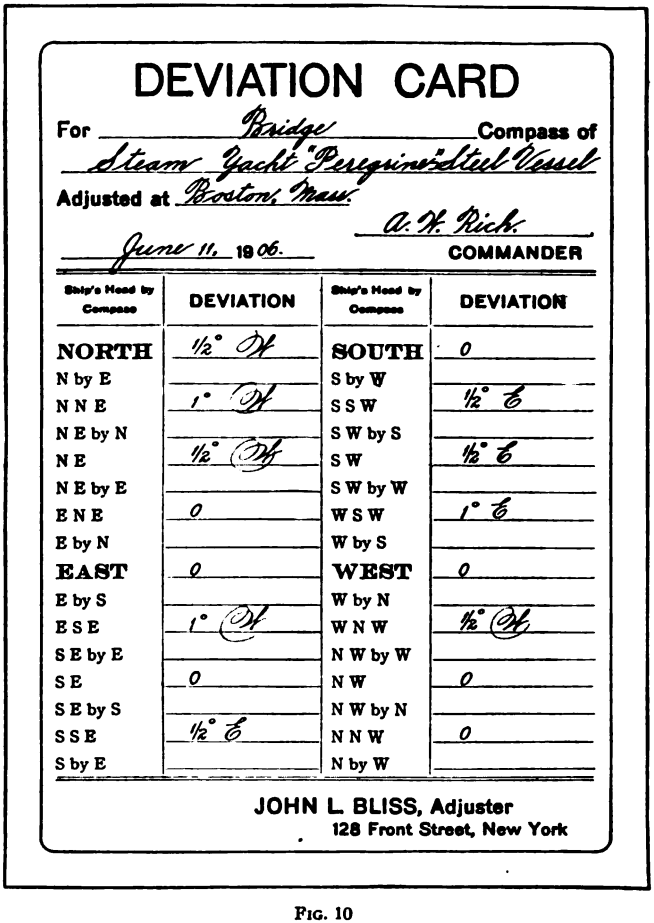


FIG. 9

mass is at right angles to the magnetic meridian or the normal direction of the needle. It is evident, therefore, when a compass is placed on board of a vessel and surrounded by masses of iron and steel, it becomes unreliable because of the influence of this metal on the magnetic needle.

16. To guard against the effect of deviation, certain manipulations are employed to reduce mechanically the error to a minimum value and restore, as far as can be done, the compass to its original function. This process is known technically as *compensating the compass*, and consists chiefly in placing suitable magnets in such position about the compass as to counteract the magnetism of the surrounding iron. Thus, if the vessel is heading west, as in the first diagram of Fig. 9, and the compass has a westerly deviation, a magnet *b* may be placed so that it will counteract the effect of the mass *a* and bring the needle back to its normal position. One, two, or more magnets may have to be used for this purpose and the vessel headed in different directions before the deviation is reduced to its least value. But even after being carefully compensated, errors may remain that may impair the usefulness of the compass.

17. Swinging For Deviation.—To find and tabulate the errors that remain after the compass has been mechanically adjusted with counteracting magnets a process of *swinging the vessel* is resorted to. The vessel is first laid in a north-and-



DEVIATION CARD

For Bridge Compass of

Steam Yacht "Peregrine" Steel Vessel

Adjusted at Boston, Mass.

June 11, 1906. A. H. Rich. COMMANDER

Ship's Head by Compass	DEVIATION	Ship's Head by Compass	DEVIATION
NORTH	½° W	SOUTH	0
N by E		S by W	
N N E	1° W	S S W	½° E
N E by N		S W by S	
N E	½° W	S W	½° E
N E by E		S W by W	
E N E	0	W S W	1° E
E by N		W by S	
EAST	0	WEST	0
E by S		W by N	
E S E	1° W	W N W	½° W
S E by E		N W by W	
S E	0	N W	0
S E by S		N W by N	
S S E	½° E	N N W	0
S by E		N by W	

JOHN L. BLISS, Adjuster
128 Front Street, New York

FIG. 10

south direction, according to permanent landmarks, and then swung successively with her bow on each of the thirty-two points of the compass; then, as the vessel is steadied on each point, the deviation is carefully noted and tabulated on a card

similar to the one shown in Fig. 10. This process of compensating the compass and tabulating the remaining deviation should always be made by a professional compass adjuster. The necessity of having the compass carefully adjusted is too great to leave the adjustment in the hands of incompetent persons. Deviation, like variation, is named east or west, according as the compass north is deflected east or west of the magnetic north.

18. Magnetic Property in Iron and Steel Vessels.—In the foregoing, to show why the deviation is different on different headings, an engine situated in the forward part of the vessel was used. The steel or iron of which the vessel is constructed may act in an exactly similar manner. When a vessel is built of iron, she acquires magnetism partly through induction from the earth and partly through the hammering and riveting necessary when constructing the hull. In conformity with laws of magnetic phenomena, this magnetism, or polarity, is concentrated in two poles, a negative and a positive, located in different parts of the vessel and the location of these poles will depend on the direction in which the vessel is built. For the sake of convenience and clearness, positive polarity is designated as red, and negative polarity as blue.

19. For example, a yacht built of steel or iron in a north-and-south direction, with her bow toward north, will have red, or positive, polarity in her forward part, and blue, or negative, polarity in her stern. The effect of this will be that the magnetism in the yacht's forward part will repel the north end of the compass needle and, similarly, the magnetism in the after part will repel the south end of the needle. If the vessel is built in a northeasterly direction, red, or positive, polarity will be found on the port bow, and blue, or negative, polarity on the starboard quarter. Again, should the vessel be built in the direction of the meridian with her bow toward the south, her stern will possess red polarity and the bow blue polarity. When built in an east-and-west direction, the side of the yacht that faces the north magnetic pole will acquire red, and the other side blue polarity. When built with her bow to south-

east or southwest, the red polarity will be on the port quarter in the former case, and on the starboard quarter in the latter case.

20. Effect of Vessel's Magnetism on Compass.—The effect of this acquired magnetism on the compass is shown in Fig. 11 and explains more clearly why the deviation is not the same on all headings. Take the case of a vessel that was built with her bow toward magnetic south and as a consequence

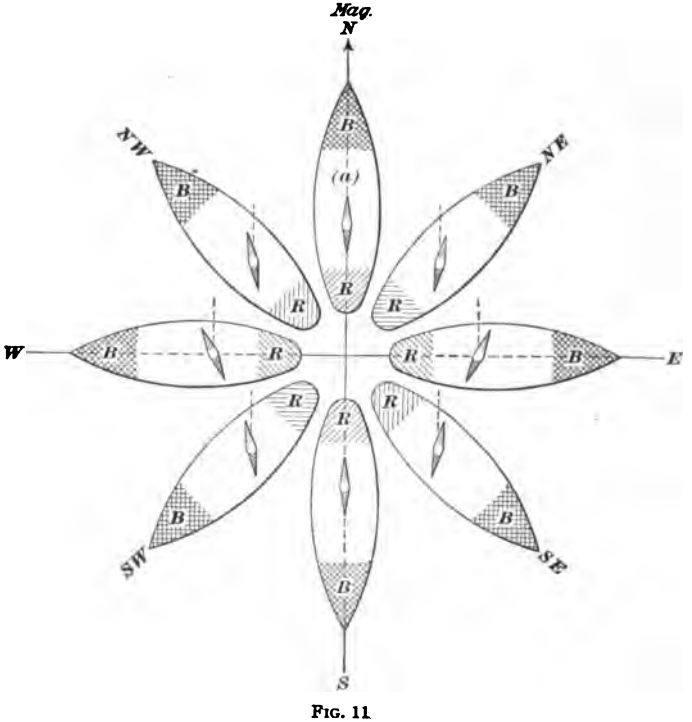


FIG. 11

has blue, or negative, polarity B in the bow and red, or positive, polarity R in the stern. Then, when heading north, or in the direction of the magnetic meridian, as in (*a*), there will be no deflection of the compass, because both magnetic poles of the yacht are in line with the directive force controlling the needle. If the yacht is swung with her bow northwest, the north-seeking end of the needle will be attracted by the blue polarity in the

bow, as shown, and cause a westerly deviation, which will gradually increase as the bow is swung toward magnetic west, on which heading the error will attain its maximum, because the magnetic poles of the yacht are then diametrically opposite the direction of the needle and are consequently exerting their greatest attraction. With the yacht's head southwest, the deviation is still westerly, but it decreases as the yacht's head is swung toward the south and disappears entirely when that point is reached. As the bow is swung toward the east, an easterly deviation will occur and this increases gradually until its maximum is attained when the yacht is heading east, as shown. In the northeast quadrant the easterly deviation will gradually decrease as the bow is swung toward the north. From the foregoing, it is evident that deviation due to acquired magnetism in a vessel built of iron or steel has contrary names and attains its greatest value in opposite semicircles; for this reason it is oftentimes called *semicircular deviation*. For vessels built with the bow north, the conditions are reversed; then a maximum easterly deviation will occur when heading west and a maximum westerly deviation when heading east.

21. All compasses are affected in a similar manner, the nature of the deviation produced, whether easterly or westerly, depending on the magnetic polarity of the vessel itself and consequently on the direction in which she was built. It is well to remember, however, that no matter where the blue and red magnetic poles of a vessel are situated (they are, as a rule, diametrically opposite each other) they will, when both are on the line of the magnetic meridian, produce no deviation whatever; but at any intermediate position they produce a maximum deviation when the line connecting the two poles is perpendicular, or at right angles, to the magnetic meridian.

22. Compensating the Compass.—The general principle of compensating a compass is to counteract the magnetic disturbance by means of magnets placed in the immediate neighborhood of the compass, and in such positions as to cause a disturbance contrary to that caused by the iron of the ship. The magnetic needle will thus be left comparatively free. This

may be illustrated as follows: Bearing in mind that the north-seeking end of the compass needle always possesses red polarity and that red polarity repels red and attracts blue, and vice versa, assume a needle to be deflected from magnetic north N to n, Fig. 12. Then, in order to bring the needle back to its normal position N, or, what is the same thing, to counteract the effect of the surrounding iron and steel, magnets may be placed in any of the positions shown at a suitable distance from, or underneath, the compass card. This in brief is the gist of compass compensation. Magnets used for this purpose are of all sizes and shapes, depending on the facilities for adjustment and the size of the compass to be adjusted. Deck magnets, which are fastened to the deck close to the compass, are flat bars from 12 to 24 inches in length and about $\frac{1}{4}$ inch by $1\frac{1}{2}$ in cross-section and protected by a thin sheeting of metal, while magnets used in binnacles provided with compensating arrangements are smaller and similar in shape and size to an ordinary lead pencil. Their magnetic polarity is usually indicated by red and blue color painted at the end of each bar.

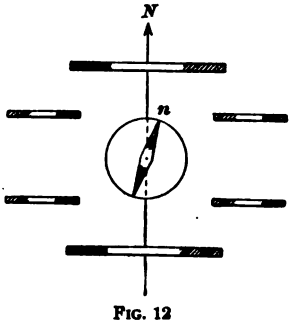


FIG. 12

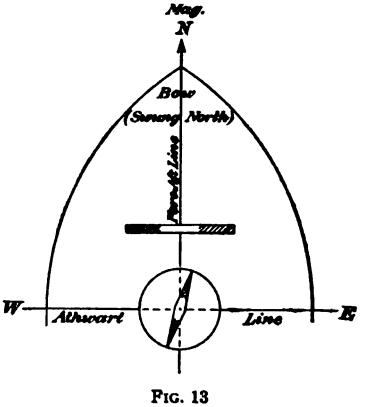


FIG. 13

23. Division of Magnetic Forces.—When mechanically adjusting a compass by means of compensating magnets, it is usual to consider the effect of the surrounding iron as a horizontal force resolved into two components, or parts, one acting in a fore-and-aft and the other in an athwartship direction. The former affects the compass when heading on easterly and westerly courses; the

latter when heading on northerly and southerly courses. By this arrangement, the compensation of a compass may be accomplished by two sets of magnets placed, respectively, on the midship and the athwartship lines intersecting under the center of the compass, as follows: swing the bow toward magnetic north in line with two permanent marks on land, the bearing between which coincides with the magnetic meridian. If the compass on this heading does not show exactly north, but is deflected to the east, as shown in Fig. 13, center a magnet across the fore-and-aft line and with its red pole to the starboard, as shown. The distance must be determined by trial; begin by placing the magnet at some distance from the compass and gradually bring it nearer until the compass shows correct magnetic north, then secure the magnet to the deck. If the needle had been deflected to the west, the red end, or pole, of the magnet should have been placed to the port side. In the event of this error being large, the ship is swung toward magnetic south and a similar operation is performed on that heading.

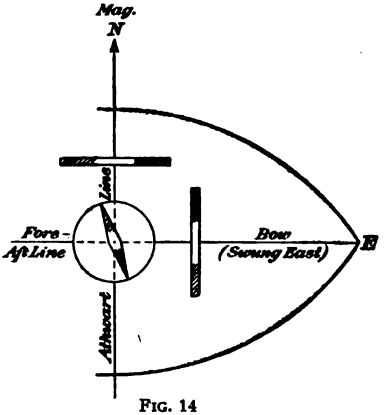


FIG. 14

24. This done, swing the bow toward magnetic east or west. If swung to the east, and the compass north on that heading is deflected to the west, as in Fig. 14, center a magnet across the athwartship line with its blue pole forwards and at a distance from the compass sufficient to correct the error. The compass north being deflected to the east, the compensating magnet is reversed. A similar operation is then performed, if necessary, with the bow swung west.

The foregoing applies to vessels not equipped with a compensating binnacle. It is necessary then to lay off chalk lines

on the deck running fore-and-aft and athwartship, having these intersect at a point vertically below the center of the compass to be compensated. The magnets are then placed perpendicular to and with their centers on these chalk lines, as shown in Figs. 13 and 14.

25. Deviation Ranges.—In many harbors, deviation ranges have been established. These consist of two fixed conspicuous objects that, when brought in coincidence, or in line, bear magnetic north from the observer. Among such ranges may be mentioned those at Delaware Breakwater behind Cape Henlopen. Charts of localities in which deviation ranges are established usually give particulars and a description of their appearance, while more detailed particulars about them are found in the United States Coast Pilot, issued by the United States Coast and Geodetic Survey.

26. Local Attraction.—Any disturbance, temporary or otherwise, due to iron, steel, motors, electric wiring, etc. in the immediate vicinity of the compass, and which is not included in the stationary equipment or metal surrounding the compass, may properly be termed **local attraction.** In this expression is included also the magnetic influence due to the locality in which the vessel happens to be—for example, when in dock alongside of iron ships, cranes, pillars, or other iron structures, or when in close proximity to iron-bearing rocks.

On small vessels, such as motor boats, the deviation from this source is greater than on larger ships because of the limited space into which articles of a magnetic character are necessarily crowded and moved about the compass. In some cases, spark coils and magnetos thoughtlessly placed close to the binnacle have effectually rendered the compass useless. There are cases on record of strandings as the result of articles or pieces of iron having been left near the compass. Any piece of steel and iron, such as hammers and monkeywrenches, will affect the compass, if brought near the card. Such articles must not be left within a radius of 6 feet from the compass. Stanchions, railings, and other fittings near a compass should preferably be of bronze or other non-magnetic substance. If made of iron, they should

not be removed while the compass is in use, from the position occupied when the compass was adjusted and swung for deviation.

27. Compass and Clutch Lever.—On small motor boats, the clutch lever is perhaps the most serious cause of rendering the compass untrustworthy. This lever, which controls the reversing gear, is usually made of iron and is placed near the steering wheel and compass, where the operator stands to manipulate both the rudder and the running of the engine. The lever acquires its magnetism, through induction, from the earth and in the case of a small compass card, in which the magnetic power is less than in cards of larger dimensions, may on certain courses deflect the compass several points. With large compass cards, the effect is less pronounced. For this reason the size of the compass card has an important bearing on the performance of the compass. Even on small motor boats, the diameter of the card should not be less than 4 inches and in order to insure steadiness and reliability only a liquid compass should be used on such craft.

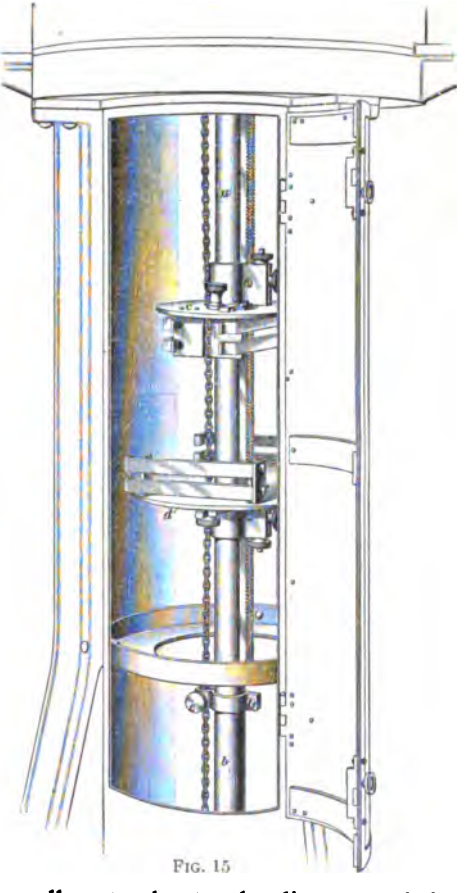


FIG. 15

28. Compensating Binnacles.—Binnacles provided with receptacles for storing magnets to counteract the effect of surrounding iron are called **compensating binnacles.** Many types of such binnacles are on the market, several being designed especially for use on motor boats. The principle of storing magnets within binnacles is the same as in securing them to the deck, the receptacles for fore-and-aft and athwartship magnets being placed exactly on the respective lines and in a plane parallel to that of the compass card when the boat is on a level keel. Usually, trays are provided within the binnacle in which the compensating magnets fit snugly and securedly, the trays being movable up or down to meet the requirements as to distance from the compass card. Thus, in the binnacle shown in Fig. 15, *c* and *d* are magnet trays sliding on a center tube *a b*. Each tray has four receptacles for the insertion of as many magnets, two on either side of the center tube, and each tray may be fastened at any desired height by racks and side clamps. The magnets are prevented from sliding out of their places by a spring, which locks the entrance to each receptacle. The upper tray *c* is generally used for the fore-and-aft magnets, and the lower one *d* for the athwartship magnets; or if required the trays may be reversed. In other types of compensating binnacles, vertical racks are provided in which magnets may be secured, one rack with receptacles for the fore-and-aft and the other for the athwartship magnets. The entire binnacle with trays, tubes, and clamps are made of non-magnetic metal, the door being fitted with locks to prevent magnets from being tampered with.

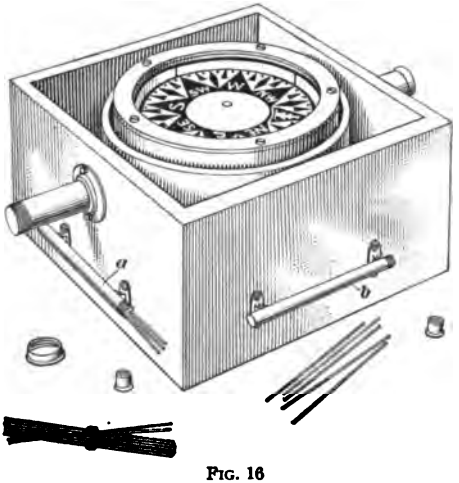


FIG. 16

29. In Fig. 16 is shown one of the many types of compasses with compensating outfit for use on motor boats. The tubes *a* and *b* attached to the sides of the box holding the compass are the receptacles for the compensating magnets, shown beside the box. The required number of such magnets are inserted in the tubes, which are then closed by screwing on the caps. It is evident that before the adjustment is undertaken the box must be accurately placed in its proper position with one pair of lubber lines in perfect coincidence with the boat's fore-and-aft line. Clamps on each side of the box may be provided for this purpose, in order that if the box is removed it may be dropped into its proper place at any time.

FIG. 17

30. Another type of power-yacht compensating binnacle is shown in Fig. 17 with its compensating chamber *a b* lowered. After the magnets are properly placed, the chamber is pushed up and secured to the lower part of the compass bowl, making the whole a compact body. The trunnioned head *c*, which is shown partly open, may be closed when the compass is not used or it may be turned so that the entire compass is exposed. This particular binnacle is fitted with an electric lamp illuminating the card from beneath; it carries also the steering wheel *d* and the necessary gearing for the control of the steering mechanism.

31. Azimuth Instruments.—For the purpose of taking accurate compass bearings, an **azimuth instrument,** or **sight-bar attachment,** should be included in the navigating outfit of seagoing power boats. This instrument is made in various forms. The simplest consists of a metal bar, of the same length as the diameter of the compass bowl, that has a small center hub which enters a socket drilled in the center of the glass covering the compass. Vertical sight vanes are pro-

vided at the ends of the bar; the navigator takes his bearings through these by swinging the vanes until they are in line with the object. A slender horizontal thread stretched in the center of the open space of the bar indicates the direction of the bearing taken.

32. In compasses not provided with a central socket for the reception of a regular azimuth instrument, a circular ring provided with sight vanes may be used. The flange of this ring, Fig. 18, is made to fit around the top of the compass bowl and can thus be swung in any desired direction; *a* and *b* are the sight vanes and *c* the horizontal wire, or thread, by which the

FIG. 18

bearings are read. The sight vanes can be turned down when the instrument is not in use. Altogether, the instrument is very easy to manipulate, and the bearing of an object may be read to the nearest degree without any difficulty. The method, in use by many, of taking bearings by extending the right hand over the compass in the direction of the object observed, does not give satisfactory results in cases where the fixing of the position of the boat is dependent on accurate bearings.

CHARTS AND THEIR USE

33. Charts are maps of the sea representing the whole or parts of certain regions of navigable waters with their adjoining coast lines. Each chart contains various particulars, peculiar to the tract of water it represents, that may aid the mariner to navigate his vessel successfully; it points out dangers and obstacles to be avoided and the shortest route, consistent with safety, by which a desired point may be reached.

34. The majority of charts used in deep-sea navigation are constructed on the Mercator's projection, and for this reason are known as Mercator's charts. All the meridians are parallel straight lines and the degrees of longitude are all equidistant; the latitude parallels are everywhere at right angles to the meridians and the distance between them increases from the lowest to the highest parallel in the same proportion as the degrees of longitude decrease on the globe. This increase is shown in Fig. 19, where *m n* are meridians and *l p* latitude parallels. The most useful feature of the Mercator's chart is that the track of a ship that steers a straight continuous course can be represented on the chart as a straight line. Thus, in Fig. 19, if a vessel sails from *a* to *b*, thence to *c* and to *d* her track appears on the chart as straight lines.

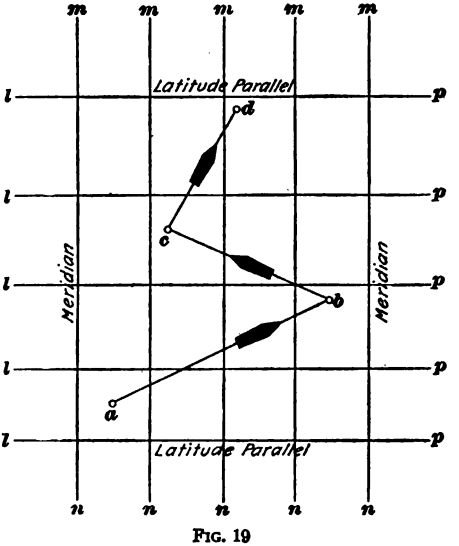


FIG. 19

35. Charts used in navigation along the Atlantic and Pacific seaboard are constructed mostly on the polyconic projection;

they are prepared and published principally by the United States Coast and Geodetic Survey. Charts of adjoining coast lines, such as those of Newfoundland, the Gulf of St. Lawrence, Nova Scotia, the West Indies, the Gulf of Mexico, etc., and charts of the Great Lakes are published by the United States Hydrographic Office. Charts constructed on the polyconic projection are used the same as those on the Mercator's projection. Courses and bearings are represented by straight lines, and distances are measured according to scales printed on the charts.

36. Classification of Charts.—With regard to the objects for which they are constructed, charts may be divided into two classes, *general charts* and *plans*. **General charts** usually embrace a large part of an ocean, an entire ocean, or a considerable extent of coast line. As a rule, they are subdivided into sailing charts and general charts of the coast. The former are intended for the use of navigators to fix the position of the ship when approaching the coast from the open ocean, or when navigating between distant ports. On these charts are recorded the offshore soundings, generally giving the 1,000-, 100-, and 50-fathom curves, the principal lights, variation curves, outer buoys, and such landmarks as may be visible at a considerable distance.

37. General charts of the coast are intended for use in coastwise navigation, when the vessel will be most of the time within sight of land, and her position fixed by bearings taken of landmarks, lights, outer buoys, and by characteristic soundings.

It is well to remember that, in general, soundings on plain white are in fathoms; those on shaded or dotted parts of the charts are expressed in feet. The information printed on charts, regarding the soundings, etc., should always be carefully read. On general charts of the coast, sounding curves indicating the range of sounding of 10, 20, 30, and 100 fathoms are shown. These curves are of great assistance when approaching or navigating along the coast. On large general charts, for instance, the chart of the North Atlantic Ocean, only the

100-fathom curve is shown. All soundings show the depth at *mean low water*.

38. Plans or **special charts** are charts that comprise a detached portion of a general chart on a large scale, such as a chart of a harbor, a small bay, the entrance to or a part of a river, the channels leading to a port, or a small part of the sea where navigation is difficult and dangerous. They generally contain the lights and buoys, the soundings and character of bottom, the leading marks, the courses through channels, dangers to be avoided, the variation of the compass, and other information that will tend to facilitate the navigation of that locality. Such plans are sometimes inserted for convenience in a corner of the general chart. Plans are usually designated as *coast charts* or *harbor charts*, according to the objects they are designed to subserve, the latter being on large scales and intended to meet the needs of local navigation.

39. Obtaining Charts.—As already stated, charts are published by the government and can be bought direct from the United States Coast and Geodetic Survey, and from the United States Hydrographic Office, Washington, District of Columbia, or from any of the agencies or branch offices, of the latter, which are located in the principal harbors along the coast.

The best way in which to order charts needed for any contemplated trip is to get a catalog of charts issued by both institutions. Copies of catalogs from the Coast and Geodetic Survey are obtained free of charge on application to the Superintendent, while for the catalog of Hydrographic Office charts a charge of 50 cents is made for each copy. The arrangement of these catalogs is very simple and readily understood.

To show the method of selecting charts, assume that the proposed trip is to be made from Gloucester, Massachusetts, to Portland, Maine. The charts covering this portion of the coast are numbered 107 and 108, as shown in Fig. 20, which is a reproduction of a similar diagram found in the Coast and Godetic Survey catalog. But in addition to these coast charts, it may be necessary to get the harbor charts of Gloucester,

No. 334, and of Portland harbor, No. 325; and if the intended trip is not direct or continuous it is also necessary to get the plans of such harbors as are included in the itinerary. As a matter

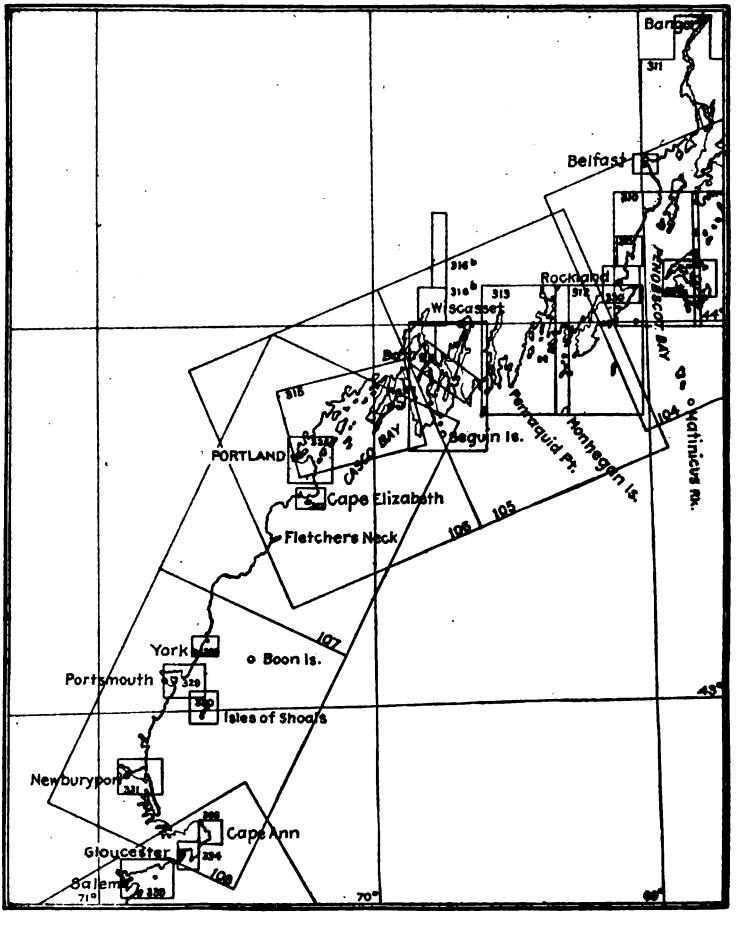


FIG. 20

of prudence, it is well to be supplied with charts covering the harbors of the entire trip, as exigencies may develop where it is necessary to seek ports not originally intended for calls. The cost of charts is so low, varying between 25 and 50 cents a piece,

as to exclude any excuse for not being provided with reliable charts when needed.

40. Reliability of Charts.—Charts issued by the government are the product of painstaking and accurate surveys and the greatest confidence may therefore be placed in them by the navigator. No private concern has at its disposal such facilities for acquiring and treating hydrographic data as the government. One precaution, however, must be taken before the chart is used and that is to see that the chart is of recent issue and bears corrections of a recent date. The official date of latest correction should be, and is, clearly stamped on the chart. As a general rule, before a chart is used the user should see that all changes in the position or character of lights, the establishment of new or the discontinuation of existing lights, buoys, artificial landmarks, etc., that have taken place since the date stamped on the chart are properly recorded. Such changes are published in a pamphlet, known as Notice to Mariners, issued weekly by the Hydrographic Office. Copies of these notices can be obtained free of charge by applying to the Hydrographic Office, to one of the branch offices, or to any of the agencies in seaboard or lake ports.

41. Signs and Symbols Used on Charts.—When a chart is properly spread out, the top of it is toward the north, the bottom toward the south, the right side to the east, and the left side to the west. If for any reason it is otherwise, north will be indicated by the direction of the meridians and by the compass diagrams situated somewhere on the chart. On a Mercator chart, the latitude scales are found on the right and left sides of the chart, and the longitude scales at the upper and lower margins of the chart. Sometimes graduations are found on a meridian and on part of a parallel situated in the central part of the chart. On coast charts, scales for nautical and statute miles, and for kilometers, are given; on harbor charts, scales for nautical miles and yards are given.

42. The extent of fairway and areas restricting navigation to limited draft is indicated by a system of curves or *fathom*

lines. These are irregular lines connecting equal depths, generally showing the limits of areas of depth of 1, 2, 3, 5, and 10 fathoms, and multiples of 10 fathoms. The areas of 1, 2, and 3 fathoms are sometimes dotted, or shaded, to distinguish them from deeper water. In fog and misty weather, these

CONVENTIONAL SIGNS AND SYMBOLS USED ON COAST AND GEODETIC SURVEY CHARTS

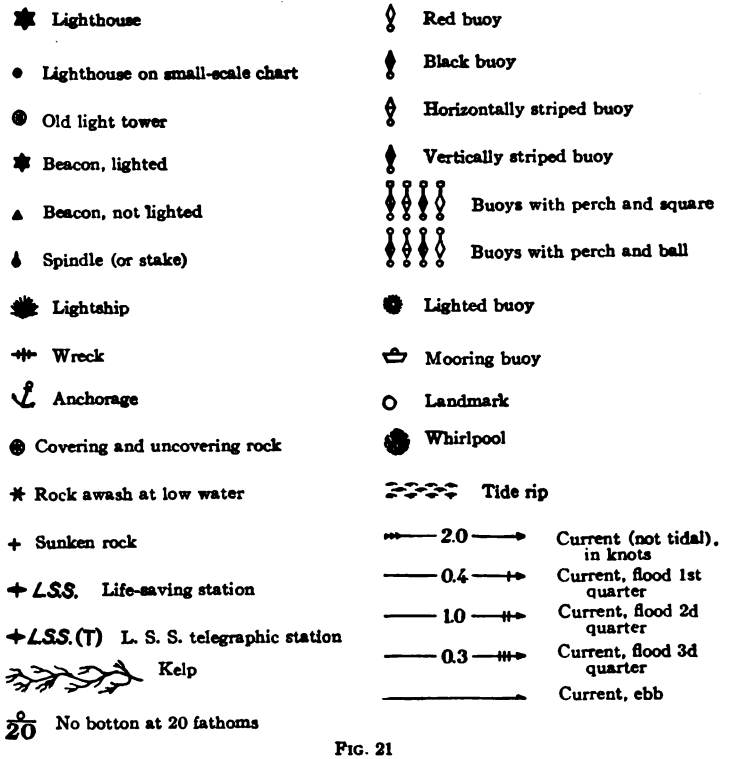


FIG. 21

sounding curves are of the greatest value to the navigator and pilot. On coast charts, all soundings are usually in fathoms, except on the dotted, or shaded, areas where they are expressed in feet. On charts of large scale, such as of harbor, bay, and rivers all soundings are expressed in feet. This is a very important point to remember.

As previously stated, however, the information printed on the charts regarding the method of expressing the soundings should always be carefully read by the navigator and then no misunderstanding will result. In fact, a navigator should, at all times, make it a point to read all the printed information on the chart before beginning to use it. Aids to navigation, such as lights, beacons, and buoys, as well as obstacles and hidden dangers are shown by symbols and by abbreviations. The signs and symbols used on the Coast and Geodetic Survey charts are shown in Fig. 21.

43. Ranges are shown by dotted and by continuous lines, the latter only for parts where a vessel may follow the range in

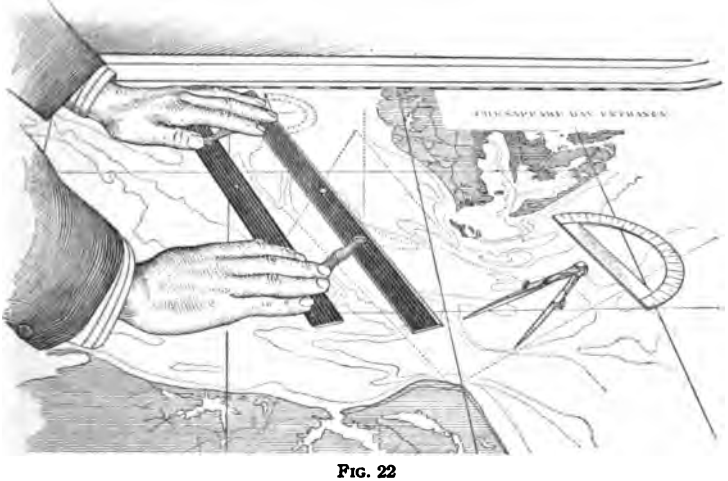


FIG. 22

safety. Bearings are given as true and expressed on later charts, according to the new compass card, in degrees from north to 360°. Charts having compass roses of the old style are being changed to conform with the new division of the card. The outer rose, divided into degrees, indicates true directions, while the inner rose, divided into quarter points, shows magnetic directions.

44. Instruments Used in Chart Work.—The principal instruments used in plotting courses and distances on a chart

are the parallel rulers, the dividers, and the course protractor, shown in Fig. 22. Provided with this outfit in addition to a lead pencil and pad for notes, almost any ordinary problem in which the chart is used may be solved. Although some practice is required before proficiency is attained, the manipulation of these accessories to the chart is very simple and should be readily acquired by any person of ordinary intelligence.

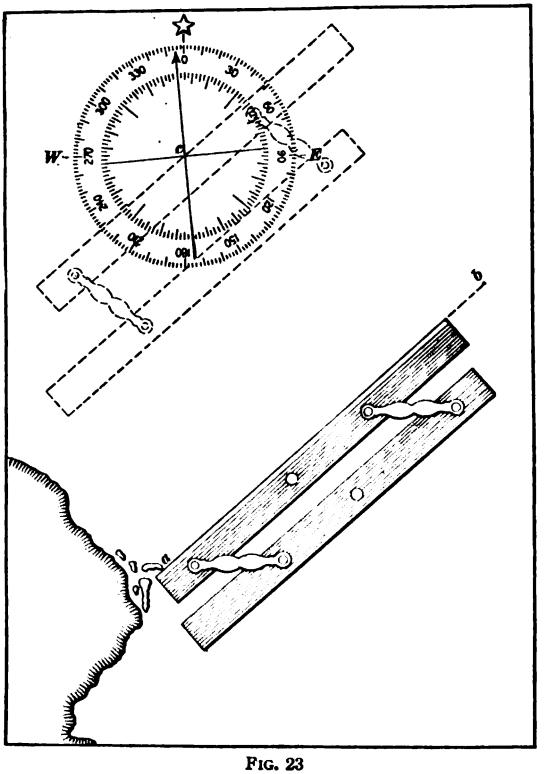


FIG. 23

45. The **parallel ruler** is usually made of ebony or gutta percha. The two parts are connected by crosspieces of brass working on pivots in such a manner that they may be spread apart or pushed together and still remain parallel to each other. They are used for the purpose of transferring the direction of a bearing, or course, to the nearest compass diagram,

or vice versa. For instance, in Fig. 23, if it is required to find the bearing between *a* and *b*, the edge of a closed parallel ruler is laid between the two places and then the upper part of the ruler is pushed forwards to the center *c* of the nearest compass diagram and the bearing read off immediately. In some cases, it may be necessary to take several steps with the ruler in order to reach the diagram, but the operation in itself is so simple as to need no further explanation. The main point, however, is to preserve the parallelism of the last step with the first.

FIG. 24

46. . Several patent parallel rulers are now on the market, among which may be mentioned the Sigsbee, the Field, and the Kay rulers. The main advantage of these over the ordinary parallel ruler is their greater spread, or the distance to which the rulers can be separated, thus doing away with the necessity of many steps in transferring courses and bearings over the chart. Another advantage is that shuffling may be made straight forwards, while the ordinary ruler has a diagonal motion due to the single cross-pieces connecting the two parts.

47. The **dividers**, shown in Fig. 24, are used to lay off and measure distances. They should be made of well-tempered steel and their points should be sharp but not too fine. When using the dividers to lay off a distance into a number of equal parts, they should be held at the top between the thumb and forefinger and the spaces stepped off by turning the instrument alternately to right and left. When laying off a distance in this manner, great care must be exercised not to press the divider points into the chart; they should be turned lightly and the final point indicated by a pencil mark, lightly applied.

48. The **course protractor** is shown in Fig. 25. The outer edge is a semicircle, with a center at *o*, and is divided into degrees and half degrees and graduated so that angles

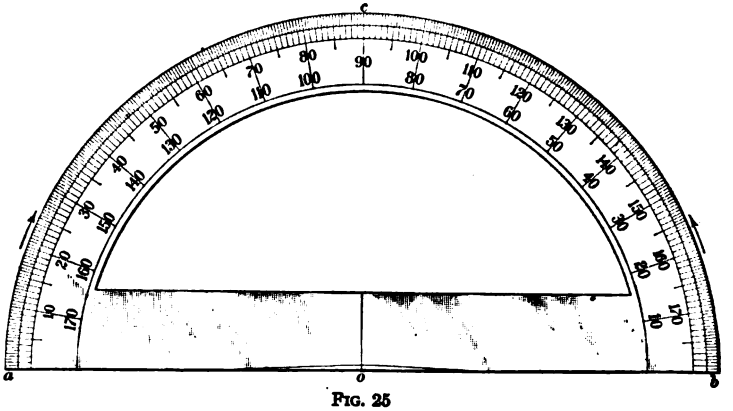


FIG. 25

can be read both ways. Thus graduations may be read from *a* to *b* or from *b* to *a*, as indicated by the arrows. The protractor is used for laying off or measuring courses or bearings;

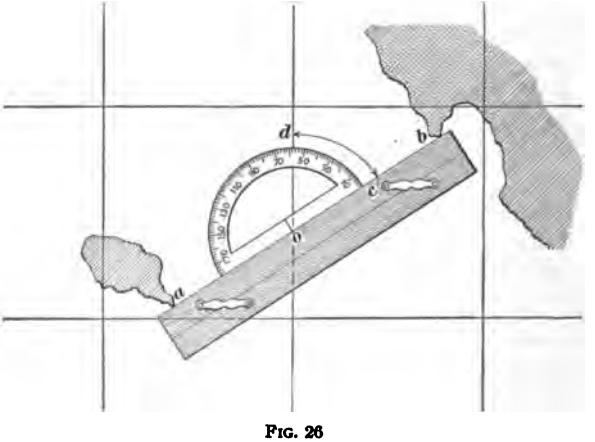


FIG. 26

it should be made of celluloid or metal and have a radius of at least 3 inches. When using the protractor, it must be placed so that the line *o a*, *o b*, or *o c* will coincide with the line forming

one side of the angle to be laid off or measured and the center *o* must be at the vertex of the angle. For instance, if it is required to find the bearing between the two points *a* and *b*, Fig. 26, a straightedge, such as a parallel ruler, should be placed between the two points, as shown; then the protractor placed along the ruler, with its center *o* on one of the meridians, and the bearing read off as indicated by the number of degrees contained in the arc *c d* reckoned from the meridian—in this case about N 57° W, or simply 57°.

Or, the two points may be connected with a pencil line drawn lightly when the center of the protractor placed at the point of

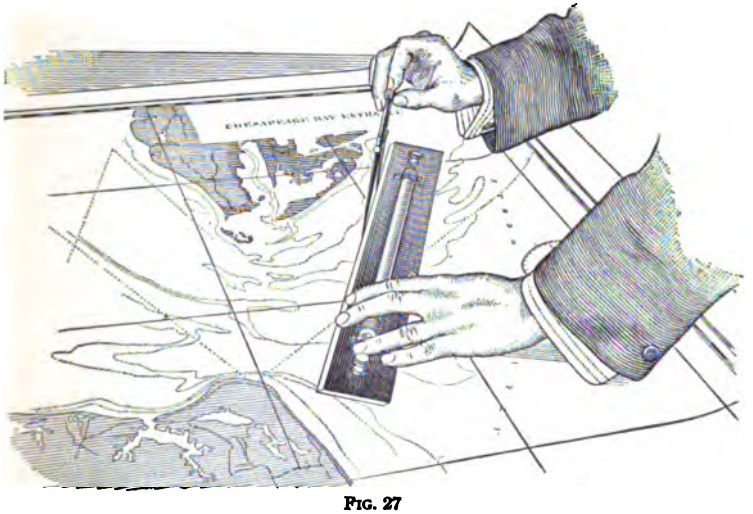


FIG. 27

intersection between the pencil line and one of the meridians will give the number of degrees required. The use of a straightedge, however, is preferred to pencil marks drawn on the chart. The protractor may be placed on any other position, provided its center is exactly at the intersection of meridian and line of bearing. It must be remembered that the course or bearing thus found is true, not magnetic.

49. In general, to find the course and distance between any two points on the chart, the edge of a ruler is placed so that it passes through and connects the points. The ruler is then

shifted to the nearest compass rose when, as already explained, the course, either true or magnetic, is read off. Usually the magnetic course is taken from the rose; then by applying to it the deviation, according to forthcoming directions, the course to steer by compass is obtained. To get the distance between the two points, the ruler is placed once more over them and the distance measured, using a suitable unit taken, by the dividers, from the scale of nautical miles. This unit is stepped off along the edge of the ruler, as shown in Fig. 27, by holding the ruler firmly with the left hand while the right hand is used to manipulate the dividers. In cases where the distance between the two points considered is small and within the limit of the scale, it may be spanned by the dividers and transferred to the scale when the required distance is obtained quickly and conveniently.

FIG. 28

THE LEAD

50. The operation of measuring the depth of the water and investigating the character of the bottom is called **sounding.** The instruments used for this purpose are the **lead** and the **sounding machine.** There are three kinds of leads, viz., the *hand lead*, the *coasting lead*, and the *deep-sea lead*. All sounding leads are similar in form to the one shown in Fig. 28, being widest at the lower end *a*, which is hollowed out for the reception of a lump of tallow. Filling this cavity with tallow is called the *arming* of the lead and the purpose of the tallow is to bring up a specimen of the bottom that it touches, so that the quality of the ground struck by the lead whether it is sand, mud, or gravel, may be compared with the description of the bottom given on the chart or in sailing directions, and the vessel's position therefrom approximately determined.

51. The **hand lead** weighs from 4 to 14 pounds and is therefore readily thrown by hand. It is well adapted for use in shallow water and for soundings in channels, rivers, and har-

bors where the depth is inconsiderable. The line attached to the hand lead should be at least 20 fathoms, or 120 feet, long.

The marking of the lead line is, of course, optional with the user, but it should be simple and readily understood. The following system of marking is in general use:

2 fathoms.....Two strips of leather
3 fathoms.....Three strips of leather
5 fathoms.....A piece of white bunting
7 fathoms.....A piece of red bunting
10 fathoms.....A piece of leather with a hole in it
13 fathoms.....A piece of blue bunting
15 fathoms.....A piece of white bunting
17 fathoms.....A piece of red bunting
20 fathoms.....A strand with two knots in it

Lead lines that are longer than 20 fathoms are marked above the 20-fathom mark with an additional knot at every 10-fathom point (at 30, 40, 50, etc.) and with a single knot at each intervening 5-fathom point, such as at 25, 35, 45, and so on. The first four fathoms of a hand lead line should be subdivided, also, into feet by suitable markings, as, for instance, narrow mountings of white twine.

52. It will be noticed that by the system of marking just given, the intervening depths of 4, 6, 8, 9, 11, etc. fathoms are without any markings and for such soundings the leadsman must depend on his own judgment. To make sure that no mistakes occur when reading off the depth, it is well to have every fathom and half fathom, up to 12 or 15 fathoms, distinguished by marks that are readily identified. Such markings may be made of strands neatly tucked in the lead line.

A representation of the marking of a lead line is shown in Fig. 29, giving the various marks up to and including 10 fathoms.

It must be remembered when marking a lead line that the distances must be counted from the bottom of the lead, as shown in the figure, and include the length of strap and lead.

53. Taking Soundings.—When sounding with the hand lead, the operator should select a place on the windward side of the vessel that will insure a free use of the arms without

the danger of falling overboard, and which at the same time is within easy hearing distance of the pilot at the wheel. Before casting the lead, the line should be nicely coiled up near by in such a manner as to insure its running out freely and without a hitch when the lead is thrown. Holding the line a few feet from the lead, the operator should swing it back and forth, or above his head, so as to impart to the lead a certain velocity and then throw it as far forward as is deemed necessary, accordto the speed of the vessel. The point a', Fig. 30, where the lead touches the bottom, will then, by the boat's forward motion, be underneath the leadsman and the sounding an up-and-down one, as indicated by the line $a\ b$. Before reading off the cast, all slack line must be pulled in and the line be absolutely taut. To make sure that the lead has reached the bottom, the leadsman should pull up his line and drop it, in rapid succession, a foot or two each way, in order to get a true "touch" of bottom, and then read off the depth by the mark on the line near the water-line $w\ w'$ of the boat. For sounding during the night, when marks cannot be seen, the distance from the operator's hand to the water-line should be known, and at each cast this distance should be deducted from the amount of line out. At night, expert leadsmen usually read off the depth by using their sense of touch in distinguishing one mark from the other. This may seem difficult at first but a little practice will soon convince any one that the faculty is readily acquired.

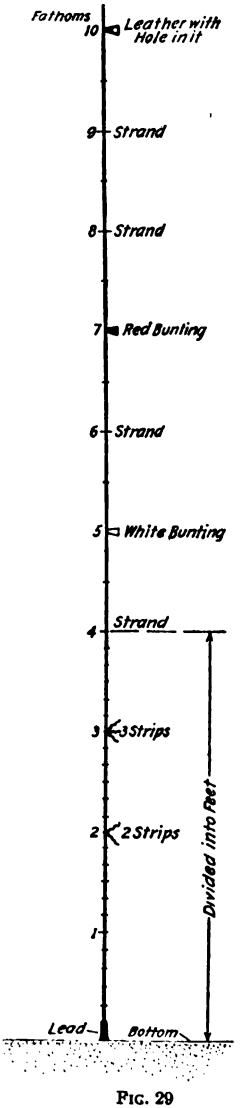


FIG. 29

54. Sounding Pole.—For small motor boats drawing but 2 or 3 feet of water or less, a **sounding pole** is an excellent substitute for a line, if light and convenient to handle. Such a pole should be marked in feet and subdivisions, the same as the lead line, by means of notches cut in the wood or by tacks placed at proper intervals.

It should be borne in mind that the up-and-down sounding is the only true one and that errors in sounding are generally in *excess;* that is, the actual depth is less than that indicated by the lead line.

55. Reduction of Soundings.—As previously stated, the depth shown on the chart is that for ordinary low water,

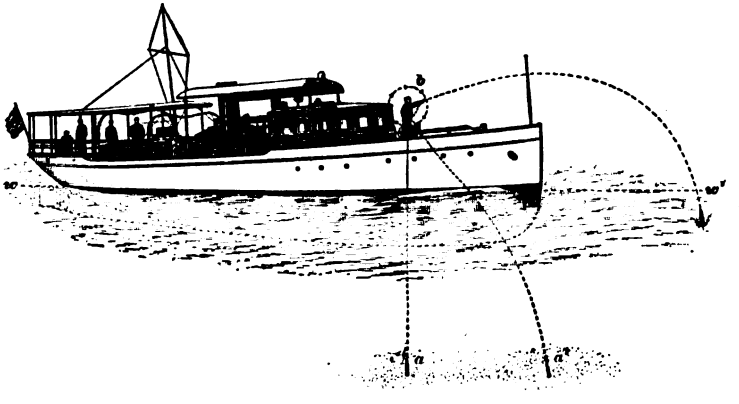


FIG. 30

or when the tide is at its minimum; hence, at any other condition of the tide a correction should be applied to the sounding obtained in order to compare it with the depth given on the chart. For general purposes, the following table for reducing soundings to the mean low-water level will be found sufficiently correct:

At high water deduct the whole range of the tide.
At the 1st hour after *high water* deduct seven-eighths of the range.
At the 2d hour after *high water* deduct three-fourths of the range.
At the 3d hour after *high water* deduct one-half of the range.
At the 4th hour after *high water* deduct one-fourth of the range.
At the 5th hour after *high water* deduct one-eighth of the range.

At the 6th hour after high water, or at low water, the soundings should agree with those given in the charts.

At the 1st hour after *low water* deduct one-eighth of the range.

At the 2d hour after *low water* deduct one-fourth of the range.

At the 3d hour after *low water* deduct one-half of the range.

At the 4th hour after *low water* deduct three-fourths of the range.

At the 5th hour after *low water* deduct seven-eighths of the range.

At the 6th hour after low water, or at high water, deduct the whole range of the tide.

Thus, if the range of the tide, or the vertical distance between high and low water, is 8 feet and a cast is taken, for instance, 2 hours after high water, three-fourths the range, or 6 feet, should be deducted from the number of feet in the sounding.

THE LOG

56. The operation of measuring the progress or speed of a ship through water is called **logging**; the two principal instruments used for logging are the *common log* and the *patent log*, of which there are several types in use. In power boats, the revolutions of the propeller afford a valuable means of ascertaining the speed, provided that a number of such measurements have been previously compared and found to agree with the actual distance run over a measured course.

57. The principle on which the **common log** is founded is as follows: Some light floating object is thrown overboard; as soon as it strikes the water, it ceases to partake of the ship's onward motion and becomes stationary. The distance of this stationary object from the ship is then measured after a certain interval of time has passed and from this measurement the approximate speed is ascertained. Primarily, the common log consist of three parts: the *chip*, the *line*, and the *glass*. The chip is the floating object thrown overboard, the line measures the distance, and the glass defines the interval of time.

58. The **log chip** is a triangular piece of light wood *c*, the lower edge of which is rounded and weighted with a strip of lead sufficiently heavy to make it float in an upright position, as shown in Fig. 31. In each corner is a hole, the log line being

knotted to the one pointing upwards; in the lower holes is fastened a sling, or bridle, at the bight of which is a peg that fits snugly into a wooden socket *t*, commonly called the *toggle*. This peg can be released from the toggle by a jerk on the log

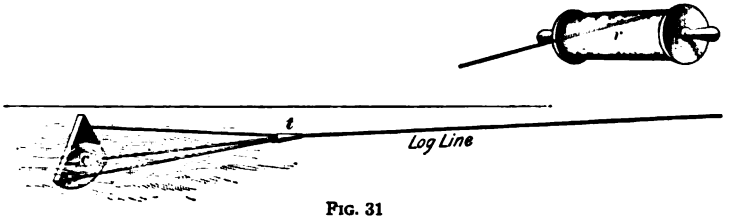


FIG. 31

line, thus allowing the chip to be pulled in with little resistance. The inboard end of the line is attached to a *reel r*, around which it is wound.

59. The first 15 to 20 fathoms of the log line from the chip is called the *stray line*, and is usually marked by a small piece of white or red bunting; the purpose of the stray line is to allow the chip to get clear of the vessel's eddy, or wake, before the measuring commences. The rest of the line, or the log line proper, is divided into parts of equal length, called *knots*, by pieces of cord fastened between the strands of the line. Each piece of cord carries the requisite number of knots, according to its order from the stray-line mark. The length of each knot, when the nautical mile is taken as the unit, is 47 feet 3 inches.

FIG. 32

60. The **log glass,** Fig. 32, is a sand glass of the same shape and construction as the old hour glass. Seagoing vessels usually carry two log glasses, one of which runs out in 28 seconds and the other in 14 seconds; the latter is used when running at a high rate of speed, when the number of knots of the line run out is doubled. If a log glass is not available a watch may, of course, be used to mark the interval of time.

61. Relation Between the Knot and the Nautical Mile.—In order to determine the speed of a ship per hour, the length of each knot must bear the same ratio to the nautical mile (6,080 feet) as the time of the log glass does to the hour. Hence, the following proportion:

As the number of seconds in an hour is to the number of feet in a mile, so is the number of seconds of the log glass to the number of feet in the knot; or,

$$3{,}600 \text{ seconds} : 6{,}080 \text{ feet} = 28 \text{ seconds} : x$$

whence, the length of the knot represented by x is

$$\frac{6{,}080 \times 28}{3{,}600} = 47.29 \text{ feet, or } 47 \text{ feet } 3 \text{ inches}$$

EXAMPLE.—What should be the length of the knot, using the statute mile (5,280 feet) as a unit, and a glass of 30 and 28 seconds, respectively?

SOLUTION.—The length of the knot in the former case would be $\frac{5{,}280 \times 30}{3{,}600} = 44$ ft., and in the latter case $\frac{5{,}280 \times 28}{3{,}600} = 41.07$ ft. Ans.

62. Method of Using Chip Log.—For logging with the ordinary chip log three men are needed: one holding the reel, one watching the glass, and one attending the line. The reel should be held clear of everything and in such a position as to allow the line to run out freely and the glass should be held ready for turning sharply when the word is given, care being taken that all the sand is in the lower bulb. The man who actually performs the logging stands at the taffrail and, after having adjusted the toggle, gathers a few fathoms of slack line in his hands. Everything ready he throws the chip and slack line into the sea, but clear of the dead water of the stern, as shown in Fig. 33. As the line straightens out, he pays out freely, guiding the line with one hand and pulling off the reel with the other. When the stray-line mark crosses the rail he calls out "turn," at which the man holding the glass instantly turns it. While the sand runs down, the line is freely paid out and when the last grain passes through the opening of the glass the holder says "stop." The logger then checks the line and reads off the number of knots and fractions of a knot run out,

which gives the speed if the 28-second glass is used, and half the speed with the 14-second glass. A smart jerk of the line releases the peg from the toggle and the line is pulled in with chip skipping along surface. In case three men are not available for logging two men can do it, one holding the reel and the other attending to both lines and glass.

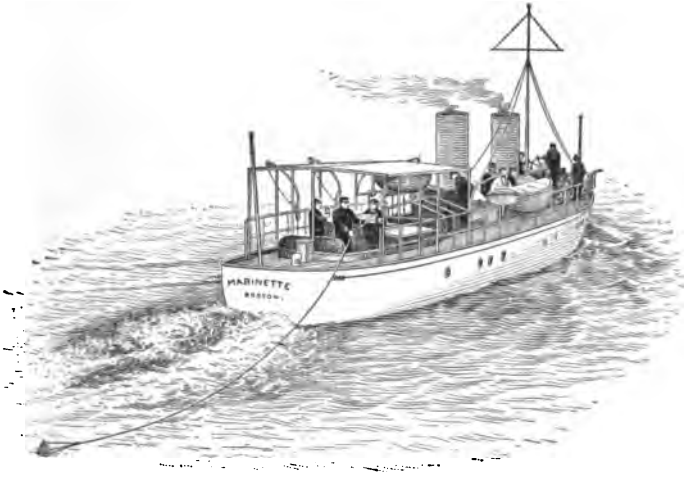


FIG. 33

NOTE.—In order to guard against errors due to an incorrect length of the knot, the log line should be examined now and then by comparing the distance between each knot with its proper length as fixed by permanent marks, such as nailheads, fastened to the deck. There may also be errors attached to the log glass; the condition of the sand or the size of the hole may be affected by changes in temperature, and it is well, therefore, to look for and correct any discrepancy found. Before a log line is marked it should be stretched and boiled in salty water; by this process the line is less liable to shrinkage and stretching from the alternate wetting and drying to which it is subjected. This applies also to the lead line.

63. At the present time the **patent log** is more extensively used than the chip log, though the latter is found on nearly all ships. On large power boats patent logs are more in evidence. There are many types of patent logs in use, but the principles on which they are constructed do not vary much. All are based on the indications given by the revolution of a small fan or screw towed by the advancing vessel.

64. A general description of the patent log is as follows: A *rotator r*, Figs. 34 and 35, attached to a line is thrown overboard and towed by the ship, thus causing it to revolve more or less rapidly, according to the rate at which it is drawn through the water; this rotary motion is transmitted to a *register R*, which, by means of a series of gears and a dial, records the number of miles run. In the *harpoon log*, Fig. 34, the rotator is connected directly with the register and the whole

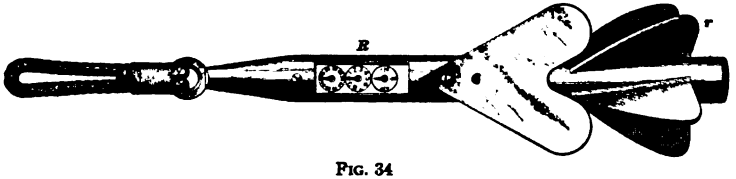


FIG. 34

is towed behind the ship. In the different types of *taffrail log* in use at present, the register is attached to the rail or other suitable place and the revolutions of the rotator are transmitted to the register by means of a plaited line, as shown in Figs. 35, 36, and 37. In the harpoon type of log, it is necessary to pull in the log in order to read the distance run; whereas, in the taffrail type, this inconvenience is done away with and the distance covered can be read off at any moment.

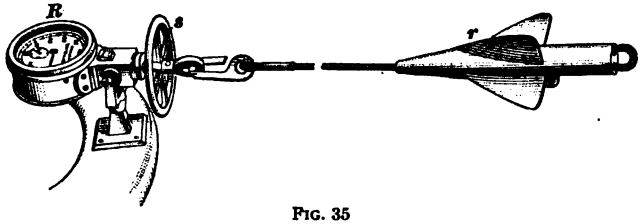


FIG. 35

The harpoon type, when in good order, is considered the more reliable, so far as accuracy in recording distance is concerned. Its disadvantages, however, are that its recording mechanism may get out of order *without the fact being known* until the log is pulled in, and that if the log is lost through damage to the line the cost of replacing it is considerable. With the taffrail log, if the rotator is lost, it can be replaced at

small cost; and its dial can be examined at any time without taking the rotator from the water.

65. For use on power yachts the taffrail patent log is the most desirable in recording the distance run; several such logs especially designed for small craft are on the market. Among these are the Kay, the Walker, the Bliss, the Durkee, the Massey, and the Negus patent logs—all of which are extensively

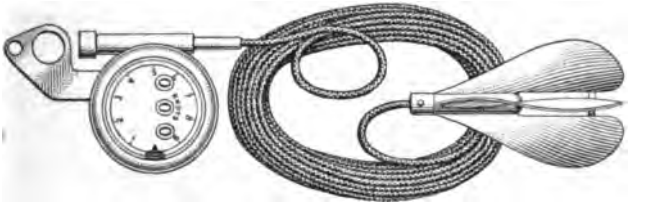


FIG. 36

used on seagoing motor boats. The Kay log, shown in Fig. 36, has a rotator weighing about 6 ounces and when packed in its box is small enough to be carried in the pocket. The Durkee log, Fig. 37, may be used also, to obtain the speed of the engine by detaching the line and attaching rubber tips provided for this purpose. Both logs are made to register the distance run either in statute or nautical miles, according to the unit used on charts of the locality in which the vessel is navigating.

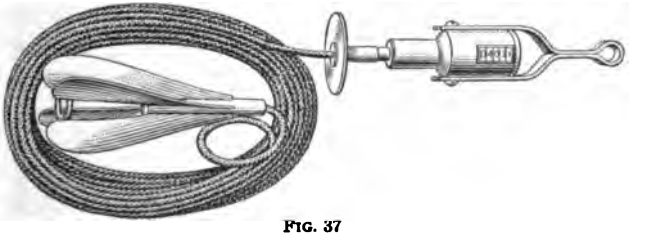


FIG. 37

66. Reliability of Patent Logs.—Patent logs are not always trustworthy. A log that runs accurately at a certain speed may not do so when the speed is changed considerably. The error for different speeds should therefore be noted, if possible, and a correction applied accordingly. The only way to note this error is to make a run from one point to another over

a measured course, the exact distance between which is exactly known and under conditions where the effect of wind and current is at a minimum.

67. The length of the log line has much to do with the correct performance of the log. Usually the proper length for different speeds is furnished by the makers and, as a rule, the higher the speed the longer the line should be. At high speed, and especially when the taffrail or place where the register is attached is high above water, the rotator sometimes has a tendency to jump above the surface of the water, causing the register to record a smaller distance than that actually covered by the boat. This may, to a certain extent, be overcome by a sinker *s* similar to the one attached to the Negus patent log

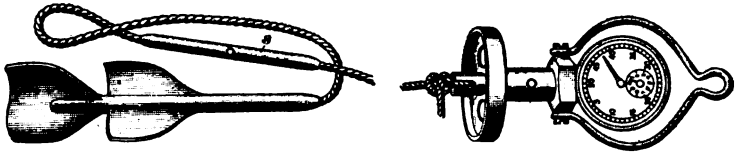


FIG. 38

shown in Fig. 38; or, if a sinker is not available, strips of sheet lead may be wrapped about the log line at a suitable distance from the rotator.

68. In connection with logs it must be remembered that the records of patent logs are records of distance run and not of speed. From the distance recorded by the register in a certain interval of time, the average speed can be found. Thus, if the distance covered during 30 minutes is 7 miles the rate of speed is 14 knots, and so on. For this reason before setting out a patent log to work, the number of miles indicated by the register must be noted; this should also be done when, during a fog, any change of the course occurs.

The log being an instrument to measure the distance run, this distance, it is well to note, is through water only and not over ground. If, during a run, the vessel is acted upon by a current, the effect is not shown by the log. Thus, if the run is made between two points in an hour, the actual distance between

which is 12 miles, but in a current running in the opposite direction at the rate of 3 miles per hour, the log at the end of the run will register 15 miles. But to cover the same distance with an equally strong current in the same direction as the tide or current runs the distance registered by the log would be 9 miles.

Like any other mechanical device from which a certain degree of accuracy is expected, the patent log should be given a reasonable amount of care. Its mechanism should be oiled daily, and when not in use it should be kept clean and dry.

THE SEXTANT

69. The **angular distance** between any two objects *a* and *b* Fig. 39, is the angle *a o b* formed by lines drawn from the observer *o* to each object; it is usually expressed in degrees, minutes, and seconds. This distance must not be confounded with the actual linear distance between the objects represented by the dotted line *a b*. No relation exists between the two, for the angular distance will remain the same at any point between the lines *o a* and *o b*, as shown in the figure, while the linear distance will vary between any two points on these lines having the same radii. Therefore, whenever the expression *angular distance* is used in connection with methods of determining the position of a vessel while in sight of land, it should be understood as the angle at the observer's eye formed by the lines connecting the eye with the two objects considered. Among the instruments used by navigators for measuring the angular distance between any two objects, as two stars or two objects seen on the horizon, the sextant is one of the most important.

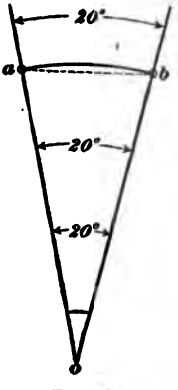


FIG. 39

70. The **sextant,** represented in Fig. 40, derives its name from the extent of its graduated arc, which is a sixth part of a circle. It consists of a metal frame *C D E*, the arc *D E* of which is graduated from 0° to 120° or 150°, each degree being

subdivided into 10′, 15′, or 20′, according to the size and perfection of the instrument. It should be stated, however, that although marked as whole degrees, the graduations on the limb are actually half degrees. The arc *D E* is usually known as the *limb;* *C* and *B* are two glass reflectors whose planes are perpendicular to the plane of the frame; *B*, called the *horizon glass*, is fixed, while *C*, called the *index glass*, is movable about the center of the instrument by means of the *index bar* *C S* to which it is affixed. The horizon glass *B*, half of which is silvered while the other half is transparent, is adjusted so that

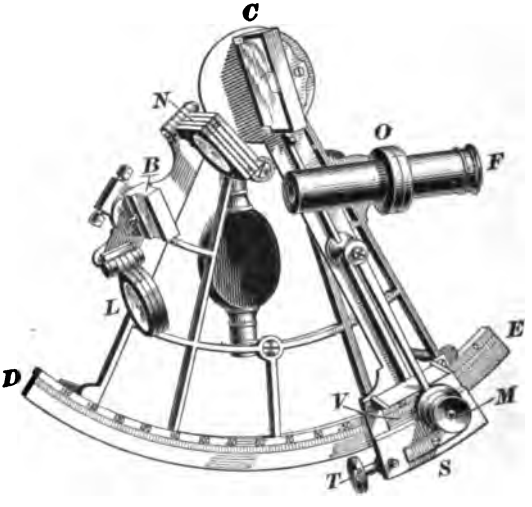


FIG. 40

its plane is parallel to that of the index glass when zero on the index bar *C S* coincides with the zero mark on the limb *D E*. The telescope *F* is screwed into the collar *O*. Upon the index bar *C S* is affixed the vernier plate *V* immediately below the graduations on the limb. The index bar is fastened to the limb by means of a clamp screw (not shown in the figure); *T* is the tangent screw by which a small motion is given the index bar after it has been partially fastened by the clamp screw; *M* is a magnifying glass for reading the graduation on the limb and vernier; *N* and *L* are colored shades that are

used to prevent the glare of the observed body affecting the eye of the person making observations.

71. To find the angular distance between two objects, S and H, Fig. 41, the instrument is first sighted toward the object S, and then the index bar $C\ I$ is pushed forwards until the image of S, formed after two reflections (from S to C, to A, to eye), coincides with the image of H seen directly through the unsilvered portion of the horizon glass. The angular distance between S and H is then equal to twice the angle $E\ C\ I$. But, as previously stated, every half degree on the graduated arc $D\ E$ is marked as a whole degree; hence, the reading of the scale gives double the angle $E\ C\ I$, which is the required angular distance between S and H.

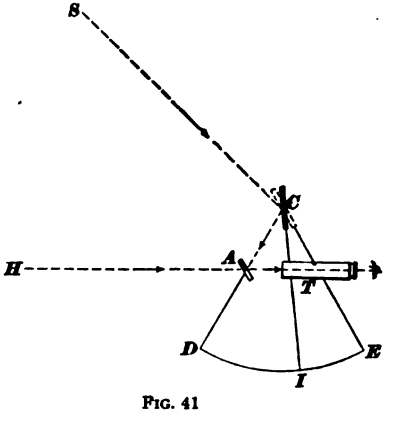


FIG. 41

72. Method of Reading the Sextant.—The limb of a sextant is divided into degrees, which are subdivided into 20′, 15′, or 10′, commencing from the right when the instrument is held before the observer. If the space between each degree is divided into three parts, an angle up to 20′ can be measured; if divided into four parts, an angle up to 15′ can be measured; if divided into six parts, an angle up to 10′ can be measured on the limb. Thus, the fineness of the graduations on the limb of the instrument, part of which is shown in Fig. 42, is 20′; that is, it cannot be read any closer than to 20′, or one-third of a degree. Now, at the end of the index bar C, just below the graduations on the limb $m\ n$, is affixed the vernier plate $a\ b$, at the right-hand side of which is a spear-shaped mark called the *index*. If this index points directly to a division on the limb, for instance, as in the figure, to that of the second degree, the reading will be at once obtained at 2°. But if, as is

more likely, the index points between two divisions, as in Fig. 43, between 1° 20′ and 1° 40′, the reading will be *about* 1° 30′.

This, however, is not sufficiently exact, and in order to obtain a more accurate reading, the graduations on the vernier are used as follows: First, read off on the limb the degrees and divisions nearest the index mark; then run the eye along the graduations on the vernier until one of its divisions that coincides exactly with one of the divisions on the limb is found.

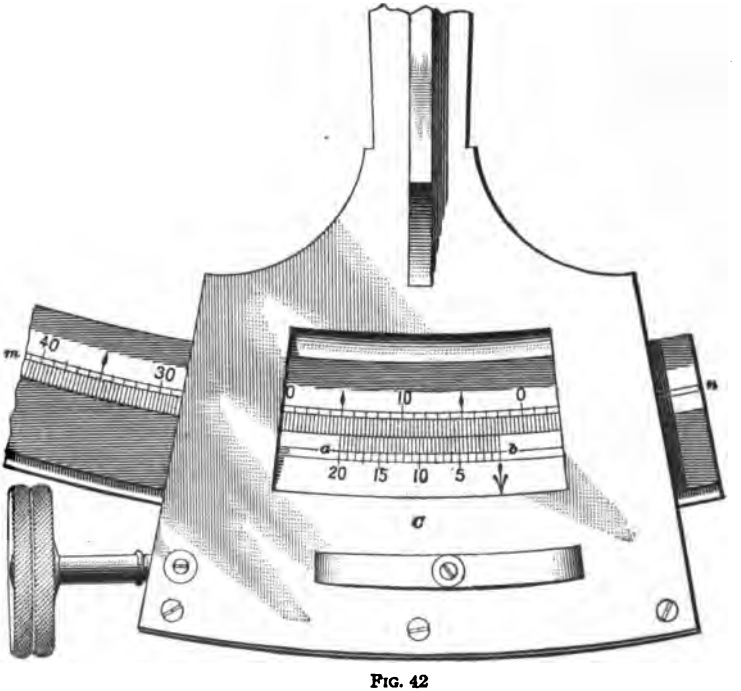


FIG. 42

Read off the number of minutes and fractions of minutes thus indicated on the vernier, and add this to the number of degrees and minutes previously read off on the limb. The result is the exact angle measured. Thus, in Fig. 43, the division on the limb nearest the index mark indicates 1° 20′; then along the graduations on the vernier we find the mark indicating 11′ to coincide with one of the graduations on the limb; adding this

number of minutes to those previously obtained, the exact angle measured will be 1° 20′+11′=1° 31′.

73. When readings are made *off the arc*, that is, when the index mark stands to the right of the zero mark, proceed as follows: Read off on the limb the number of degrees and minutes from the zero mark to the division nearest the index mark (left side) and add to this the number of minutes, read toward the right, from the last mark on the vernier to the coincident division. Thus, on the limb in Fig. 44, there is 1° 20′, and from the last, or 20′, mark to the coincident division on the vernier there is 6′. Hence, the measured angle is 1° 20′+6′=1° 26′.

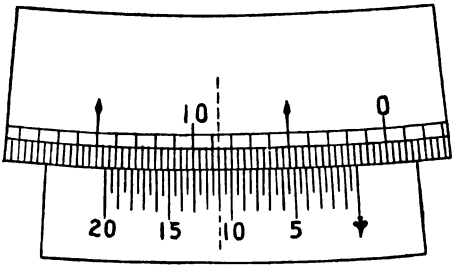


FIG. 43

74. When the first attempt is made to read a sextant, one will probably see several divisions on the limb and the vernier that appear to coincide; this, however, is only a mistake of the inexperienced. After some practice a person will soon be able to single out the division on the vernier that coincides exactly with the one on the limb. When reading a sextant, the instrument should be held in a position that the light will fall directly on the graduated arc; and when using the magnifying glass attached to the instrument it is better not to keep the eye too close to it. In Fig. 45 is shown the correct way of holding the sextant when reading a measured angle. To attain proficiency in reading the sextant one must practice with the index set in various positions.

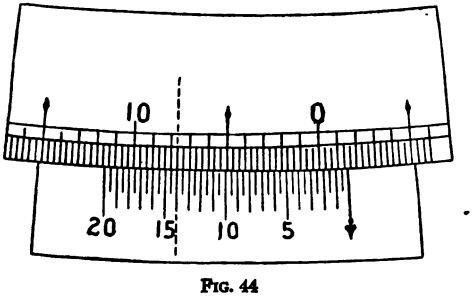


FIG. 44

75. Index Error.—The error resulting from the index glass not being parallel to the horizon glass when the index mark is at zero is called the **index error.** This error is frequently found on sextants, but, as a rule, it is not removed unless it is larger than 3′ or 4′; if less than that, its amount is applied to the observed angle, according to its sign. To determine the index error by means of the sea horizon, or by a star, proceed as follows: Select a day when the sea horizon

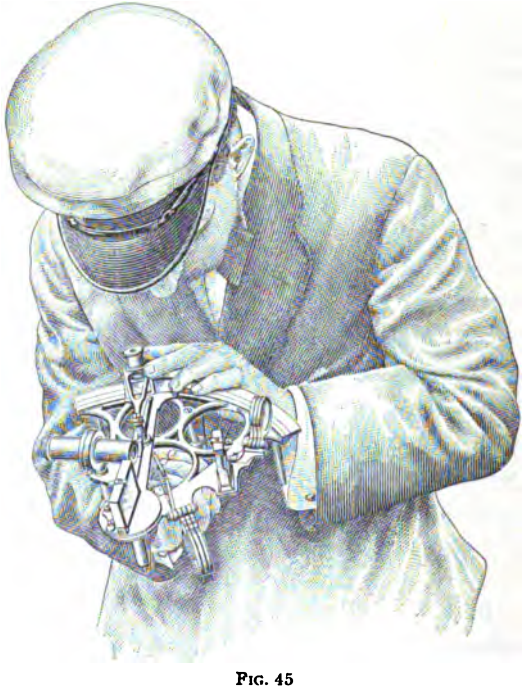


FIG. 45

is well defined. Place the index mark exactly at zero and direct the instrument, holding it in a perpendicular position, toward the horizon. Then, if that part of the horizon seen direct through the transparent portion of the horizon glass does not coincide with the reflected part, move the index bar until it does, and tighten the clamp screw; the angle then read off is the index error and is named as follows: If the zero on the vernier

is to the left of the zero on the arc, the index error is *subtractive;* if it is to the right, the error is *additive.*

Thus, in Fig. 44, the index error would be + or additive, because the zero on the vernier (indicated by a spear-shaped mark) falls to the right of the zero (0) mark on the graduated arc. In Fig. 43, the index error would be − or subtractive.

76. Measuring Horizontal Angles.—There are several methods, in coast navigation, of fixing a ship's position in which a sextant may be used with advantage when measuring the required horizontal angles. For this reason, a person should familiarize himself in measuring with a sextant the angular distance between any two objects seen on the horizon. A little practice will soon show that it is comparatively easy to do this. First of all it is necessary to learn to read angles on the sextant. When practicing place the index bar in different positions and note each angle indicated, following the directions already given. Having mastered the reading of the sextant, any two distant objects in sight, for instance, two chimneys or other conspicuous objects, should be selected. Then, with the index bar placed on zero, a sight at one of the objects is taken, the instrument being held in a horizontal position, with the right hand,

FIG. 46

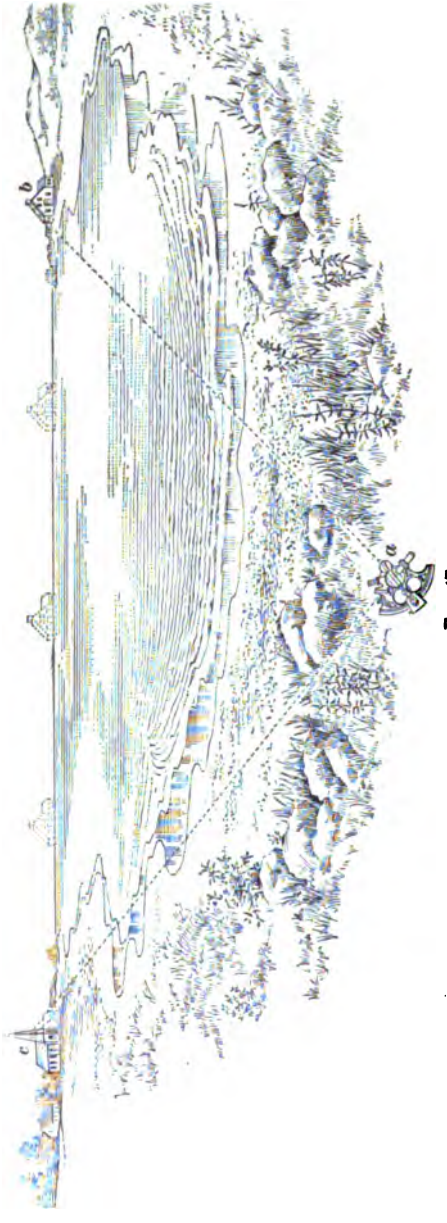


FIG. 47

and the left hand manipulating the clamp screw, as shown in Fig. 46. Then, releasing the clamp screw, the index bar is gently pushed forward following the reflected object in the silvered portion of the horizon glass. When the reflected image of the first object is close to the second object seen direct through the unsilvered part of the horizon glass the clamp screw should be fastened and a more close coincidence of the two objects obtained by using the tangent screw.

77. To illustrate the foregoing, assume that an observer was stationed at *a*, Fig. 47, and that it was required to find the angular distance between the house *b* and the church *c*. The telescope of the sextant is first sighted on the house *b* with the index bar on the zero mark. The bar is then

pushed slowly forward, trailing, as it were, the house *b* along a horizontal line until, as shown by the dotted images, it covers the church at *c*. By means of the tangent screw, the chimney on the house *b* is brought in exact coincidence with the tower of the church *c*, when the angular distance between the two objects may be read off on the graduated arc of the sextant. To clearly distinguish the reflected image from the one seen direct, turn up one of the colored shades before the index glass. This will give the reflected image a light tint, rendering it distinct from the object seen direct through the transparent portion of the horizon glass. In measuring horizontal angles, it is necessary to hold the sextant so that the reflected image is not

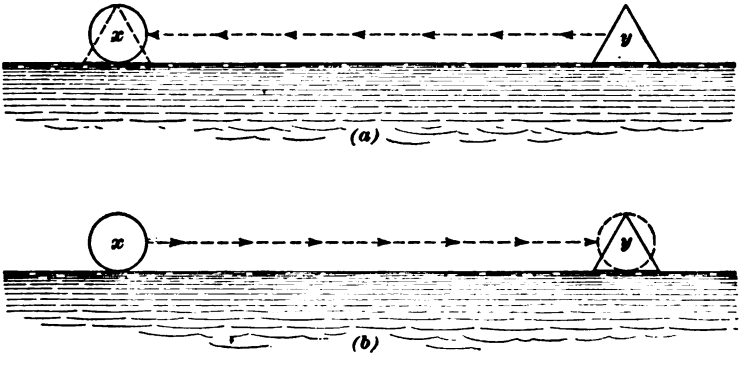


FIG. 48

dropped from sight during its transmission to the second object. The *dropping* is caused by the tilting of the instrument. By a little practice, however, this is readily overcome.

78. In cases of measuring angles at night between two lights the one with steady and prolonged exhibition should be selected for transmission by reflection. To make this clearer, assume that *y*, Fig. 48 (*a*), represents a fixed light and *x* a flash light. If the angular distance between the two lights is to be measured, it is evidently more convenient to see *y* by reflection and *x* direct; therefore, *x* is used as the base and *y* is brought in contact with *x*, the instrument being held *face up*. Again, if the conditions are reversed, that is, *x*, Fig. 48 (*b*), being a fixed

light and y a flash light, y, for similar reasons, is used as the base and x is brought into contact with it, the instrument being held horizontally, *face down*. In case both lights are flash lights, the one having the longer or more frequent interval of display should be brought into contact with the other.

CORRECTION OF COURSES

METHODS AND RULES

79. Classification of Courses.—When about to make a run from one place to another, both of which are shown on the chart, one of the first things to be done is to determine the course to steer in order to follow the shortest and most convenient navigable route connecting the places. If the run is of considerable length and must be made at night or during foggy weather it is necessary to know the exact compass course to steer.

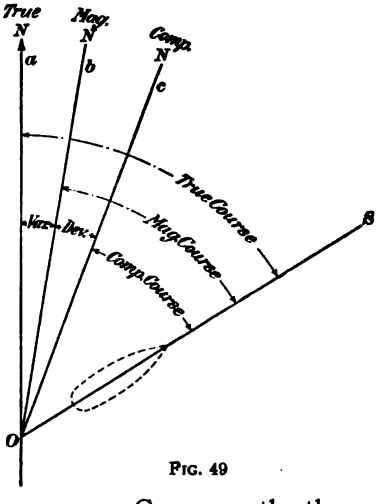


FIG. 49

As the compass may be affected by variation and deviation, there may be three distinct meridians known as the true, or geographical, meridian, the magnetic meridian, and the meridian, or direction, indicated by the north-and-south line of the compass. Consequently, there are three kinds of courses known as *true course*, *magnetic course*, and *compass course*, depending on whether the direction in which the vessel heads is referred to the true, the magnetic, or the compass north.

80. As shown in Fig. 49, the **true course** is the angle $a\ O\ S$ formed between the vessel's track $O\ S$ and the true, or geographical, meridian, as indicated on charts.

81. The **magnetic course** is the angle *b O S*, Fig. 49, formed by the vessel's track and the magnetic meridian. By allowing for the proper amount of variation in the locality considered, the true course may be converted into the magnetic course and vice versa, and if the variation should happen to be 0°, then the true course and magnetic course are the same.

82. The **compass course** is the angle *c O S*, Fig. 49, formed by the vessel's track and the north-and-south direction indicated by the compass. This course differs from the magnetic course according to the amount of the deviation; and it differs from the true course by the combined amount of the variation and deviation, both of which must be applied to the true course taken from the chart, in order to find the compass course, or the course to steer.

83. Applying Correction to Each Form of Compass Card.—As previously explained, there are two forms of compass cards in use. When the new form of compass card, or rose, is used, in which the degree graduations are marked so as to increase continuously in a clockwise direction from 0° to 360° at N, the operation of course correction is much simpler than when the old form of card is used, in which the degree graduations increase from 0° at N and at S, to 90° at E and at W.

The reason for this is that in the first case the graduations increase in one direction only, and therefore a simple rule that applies to the entire compass rose can be given for the addition and subtraction of the corrections. However, in the second case, the compass rose is divided into four quadrants in which the graduations increase in opposite directions, and hence the navigator must decide for himself whether the correction should be added or subtracted, after first determining from the proper rule whether the correction is to be applied to the right or to the left.

84. Caution.—When applying the course corrections, the compass card should be considered as representing, on a small scale, the visible horizon, on which are shown the compass directions. *Hence, the operator should consider himself to*

be stationed at the center of the compass card, looking in the direction of the course to be corrected, and then apply the correction to the right or left as directed by the rules about to be given. Thus, one point to the right of E N E is E by N, and two points to the left of E N E is N E; similarly, two points to the right of S S W is S W, and one point to the left is S by W.

85. Finding Courses With New Form of Compass Card.—When using the new form of compass card, the following rules should be observed:

Rule I.—*To find the compass course from the true course of the new form of card, add westerly variation and deviation, and subtract easterly variation and deviation.*

Rule II.—*To find the true course from the compass course on the new form of card, subtract westerly variation and deviation, and add easterly variation and deviation.*

From these rules and the illustrative examples that are to follow, it will be seen that when the total correction to be applied is east, the compass course is less than the true course; and when it is west, the compass course is greater than the true course. As an aid to the memory, this may be stated briefly as follows:

When correction is *east*, compass course is *least*
When correction is *west*, compass course is *best*

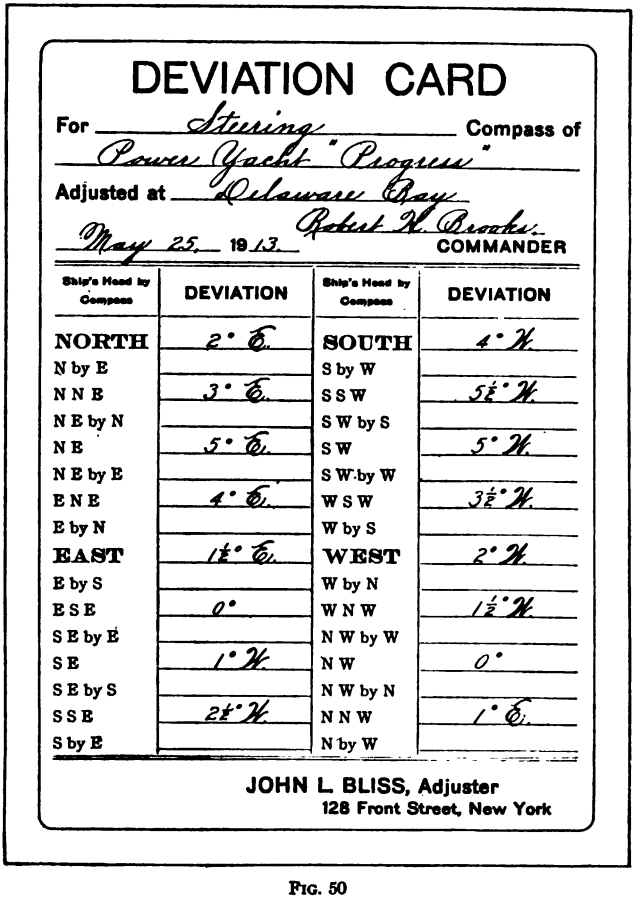
86. Finding Courses With Old Form of Compass Card.—When using the old form of compass card the following rules should be observed:

Rule I.—*To find the compass course from the true course on the old form of card, apply westerly variation and deviation to the right, and easterly variation and deviation to the left.*

Rule II.—*To find the true course from the compass course on the old form of card, apply westerly variation and deviation to the left, and easterly variation and deviation to the right.*

87. Finding Variation and Deviation.—In every case of course correction, it should be carefully borne in mind that the value of variation to be applied is that given on the chart

for the locality being navigated. Also, the amount of deviation must be that tabulated on the deviation card, Fig. 50, of the yacht's steering compass, for the direction in which the vessel heads. This is necessary because, as previously stated, the



DEVIATION CARD

For Steering Compass of
Power Yacht "Progress"
Adjusted at Delaware Bay
May 25, 1913. Robert N. Brooks.
COMMANDER

Ship's Head by Compass	DEVIATION	Ship's Head by Compass	DEVIATION
NORTH	2° E.	SOUTH	4° W.
N by E		S by W	
N N E	3° E.	S S W	5½° W.
N E by N		S W by S	
N E	5° E.	S W	5° W.
N E by E		S W by W	
E N E	4° E.	W S W	3½° W.
E by N		W by S	
EAST	1½° E.	WEST	2° W.
E by S		W by N	
E S E	0°	W N W	1½° W.
S E by E		N W by W	
S E	1° W.	N W	0°
S E by S		N W by N	
S S E	2½° W.	N N W	1° E.
S by E		N by W	

JOHN L. BLISS, Adjuster
128 Front Street, New York

FIG. 50

variation is not the same in all localities, and the deviation also varies for different directions of the vessel's head.

88. When finding the compass course from the true course, the variation should always be applied first so as to obtain

the magnetic course; the deviation corresponding to the magnetic course given in column 3 of Table II is then applied, the result being the compass course. In case the magnetic course does not agree with any of the values given in column 3, the deviation may, if small, be taken out for the value in column 3 corresponding most nearly to the magnetic course.

TABLE II

DEVIATION TABLE

1	2	3	1	2	3
Ship's Head (Course) by Standard Compass	Deviation	Correct Magnetic Course Made Good	Ship's Head (Course) by Standard Compass	Deviation	Correct Magnetic Course Made Good
North	14.0° W	N 14.0° W	North	14.0° W	N 14.0° W
N by W	16.5° W	N 28.0° W	N by E	11.0° W	North
N N W	18.5° W	N 41.0° W	N N E	7.5° W	N 15.0° E
N W by N	19.0° W	N 53.0° W	N E by N	4.0° W	N 30.0° E
N W	19.0° W	N 64.0° W	N E	1.0° W	N 44.0° E
N W by W	17.0° W	N 73.0° W	N E by E	1.5° E	N 58.0° E
W N W	14.5° W	N 82.0° W	E N E	4.0° E	N 71.5° E
W by N	11.0° W	West	E by N	5.5° E	N 84.0° E
West	7.0° W	S 83.0° W	East	7.0° E	S 83.0° E
W by S	2.5° W	S 76.0° W	E by S	8.0° E	S 71.0° E
W S W	1.5° E	S 69.0° W	E S E	9.0° E	S 58.5° E
S W by W	5.5° E	S 62.0° W	S E by E	10.0° E	S 46.0° E
S W	9.0° E	S 54.0° W	S E	11.0° E	S 34.0° E
S W by S	11.5° E	S 45.0° W	S E by S	12.0° E	S 22.0° E
S S W	13.0° E	S 35.5° W	S S E	13.0° E	S 9.5° E
S by W	14.0° E	S 25.0° W	S by E	13.5° E	S 2.0° W
South	14.0° E	S 14.0° W	South	14.0° E	S 14.0° W

When finding the true course from the compass course, it is customary to apply deviation first, which gives the magnetic course, and then to apply the variation, which gives the required true course. In general, however, it may be said that the order in which the corrections are applied does not matter, because if the correct values are used and they are properly applied, the same result is obtained.

APPLICATION OF RULES

89. Finding Compass Course From True Course. In order to make it clear just how to proceed when converting a true course into a compass course, the following examples are given:

EXAMPLE 1.—A yacht is in the vicinity of Long Island where the variation is about 10° W. The true course from her present position to a known lighthouse shown on the chart is found to be 130° on the new form of compass rose. What should be her compass course to reach the light, if the deviation is assumed to be 6° E?

SOLUTION.—Applying rule I, art **85**, gives for the compass course:

True course = 130°
Variation = 10° W (add)
Magnetic course = 140°
Deviation = 6° E (subtract)
Compass course = 134°
Or = S E, nearly. Ans.

EXAMPLE 2.—The true course, according to the chart, from a certain place to another place is N 48° W; the mean value of variation for the locality is 5° E. Find the course to steer by the compass, using the deviation given in Table II.

SOLUTION.—Applying rule I, Art. **86**, and using a diagram like that shown in Fig. 51, the compass course is:

True course = N 48° W
Variation = 5° E (to left)
Magnetic course = N 53° W
Deviation (for N 53° W magnetic) = 19° W (to right)
Compass course = N 34° W
Or = N W by N, nearly. Ans.

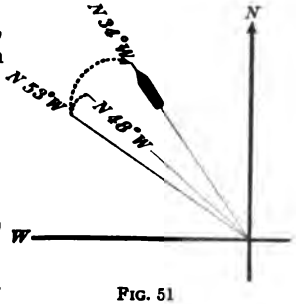


FIG. 51

NOTE.—When correcting courses, it is a good idea for the beginner to make use of a diagram—no matter how roughly drawn—representing that portion of the compass card in which the course to be corrected lies. This diagram will be found especially helpful when using the old form of compass card, in which case, the observer considers himself to be at its center and applies the corrections according to the proper rule.

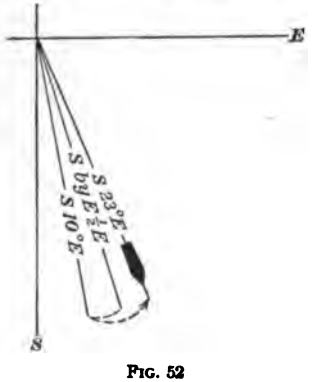
EXAMPLE 3.—The true course from the position of a motor boat to her home port is S by E ½ E, the value of variation given on the chart is 7° W,

and the deviation is that given in Table II. What course should be set on the compass in order to reach the port?

SOLUTION.—Applying rule I, Art. **86**, and using the diagram shown in Fig. 52, the compass course is:

True course is S by E ½ E = S 17° E (nearly)
Variation = 7° W
Magnetic course = S 10° E
Deviation (for S 10° E magnetic) = 13° E (to left)
Compass course = S 23° E
Or = S S E, nearly. Ans.

EXAMPLE 4.—From the chart, it is found that the true course from Boston light vessel to Egg Rock light in Boston Harbor, is 311½°. The variation shown is 13½° W. What compass course should be steered to reach Egg Rock light, assuming the deviation found from the deviation table of this compass to be 12½° W?



SOLUTION.—Applying rule I, Art. **85**, the compass course is:

True course = 311° 30
Variation = 13° 30′ W (add)
Magnetic course = 325° 0′
Deviation = 12° 30′ W (add)
Compass course = 337° 30′
Or = N N W. Ans.

EXAMPLE 5.—According to chart the true bearing of Boston lighthouse, from the vessel's position, is due west. What course should be set on the compass in order to make the light, assuming the variation to be 13° W and the deviation 4° E?

SOLUTION.—Applying rule I, Art. **85**, the compass course is:

True bearing, or course is west = 270°
Variation = 13° W (add)
Magnetic bearing, or course = 283°
Deviation = 4° E (subtract)
Course to steer = 279°
Or = W ¾ N nearly. Ans.

It should be understood, that if the course, or bearing, between two positions on the chart are determined from the

magnetic rose, then the compass course, or bearing, is found by the application of deviation only.

NOTE.—For navigating a motor boat or other small vessel, it is sufficiently accurate to give the course and corrections to be applied to the nearest half degree; then the resulting course may be expressed to the nearest whole degree or fractional point, as desired.

90. Finding True Course From Compass Course. When it is necessary to find the true course corresponding to a given compass course, the procedure is as illustrated by the examples that follow. Ordinarily, the occurrence of this case may not be as frequent in motor-boat navigation, as that just treated, but nevertheless, it should be thoroughly understood.

EXAMPLE 1.—From Scotland Bell lightship, a power yacht steers by compass 176° and the variation in this locality is about 9° W. If the tabulated deviation of the compass for this heading of the yacht is 13° E, what is the true course made good?

SOLUTION.—Applying rule II, Art **85**, the true course is:

Compass course = 176°
Deviation = 13° E (add)
Magnetic course = 189°
Variation = 9° W (subtract)
True course = 180°
Or = south. Ans.

EXAMPLE 2.—A vessel steers S by W by compass, the variation, according to chart, is 12° E, and the deviation according to Table II; find the true course.

SOLUTION.—Applying rule II, Art. **86**, and using the diagram in Fig. 53, the true course is:

Compass course = S by W
Or = S 11° W
Deviation (for S by W) = 14° E (to left)
Magnetic course = S 25° W
Variation = 12° E (to right)
True course = S 37° W. Ans.

EXAMPLE 3.—The compass course is N W, variation 19° E, deviation for heading 26° W; find the true course.

SOLUTION.—Applying rule II, Art. **86**, and using the diagram in Fig. **54**, the true course is:

Compass course = N W
Or = N 45° W
Variation = 19° E (to right)
Magnetic course = N 26° W
Deviation = 26° W (to left)
True course = N 52° W. Ans.

EXAMPLE 4.—A vessel approaching Cove Island light, on Georgian Bay, is steering east by her compass. Using the deviation given in Table II and the mean variation 6° W, what true course is she making?

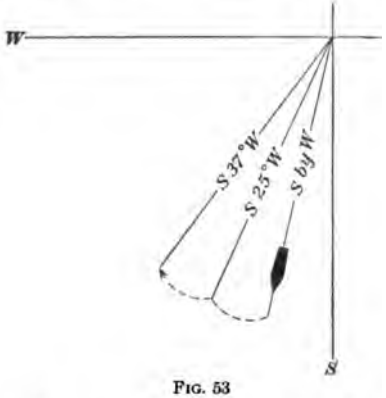


FIG. 53

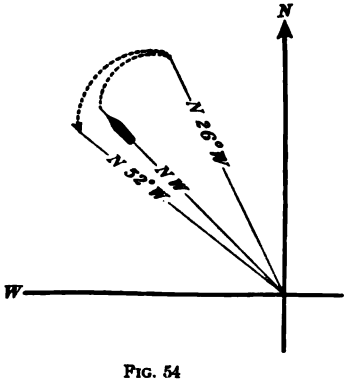


FIG. 54

SOLUTION.—Applying rule II, Art **85**, the true course is:

Compass course, east = 90°
Deviation for east = 7° E (add)
Magnetic course = 97°
Variation = 6° W (subtract)
True course = 91°
Or = S 89° E. Ans.

91. Finding True Bearing From Compass Bearing. When running along a coast in sight of some known object, the vessel's position can readily be plotted on the chart if the bearing and distance of the object is known, as will be explained in another Section. The bearing of the object taken by the compass must, however, first be converted into the true bearing (or magnetic bearing, according to the chart used). This procedure is exactly similar to that of finding the true course from

the compass course, because the true bearing of an object is the same as the true course to that object. But it should be remembered that *the deviation applied must be that for the compass direction in which the vessel is heading when the bearing is taken, regardless of the bearing of the object itself.* This is illustrated by the following examples:

EXAMPLE 1.—A motor boat entering Drake's Bay, California, is heading by compass N E by E, and finds that the compass bearing of the light at the west end of Point Reyes is N by E. The variation for the locality is 17° E. Find the true bearing of the light, using the deviation in Table II.

SOLUTION.—Applying rule II, Art. **85**, the true course is:

Compass bearing is N by E = 11° 15′
Deviation for N E by E = 1° 30′ (add)
Magnetic bearing = 12° 45′
Variation = 17° 0′ E (add)
True bearing = 29° 45′
Or = N 30° E, nearly. Ans.

EXAMPLE 2.—A yacht in Lake Erie, bound for Cleveland, is steering S W by her compass, and the deviation for this heading is as given in Table II. If the variation of the locality is 5° W, what is the true bearing of the light on Long Point if its bearing by compass is 356°?

SOLUTION.—Applying rule II, Art **85**, the true course is:

Compass bearing = 356°
Deviation (for S W) = 9° E (add)
Magnetic bearing = 365°
Variation = 5° W (subtract)
True bearing = 360°
Or = North. Ans.

EXAMPLES FOR PRACTICE

1. From Barnegat light, on the Jersey coast, the true course to be run is S 79° E; the variation is 8° W, and the deviation is according to Table II. What course should the yacht steer by compass? Ans. S 79° E

2. The true course from a motor-boat's position to her destination is 285°. Assuming the deviation to be 8° W, and the variation 17° E, what should be her compass course? Ans. 276°

3. In order to fix the vessel's position on the chart, a compass bearing of the light at Sea Girt Inlet, New Jersey, is taken, and found to be 240°.

At this instant, the vessel is steering by compass, due south, the variation is $8\frac{1}{2}°$ W and the deviation is as given in Table II. Find the true bearing of the light. Ans. $245\frac{1}{2}°$

4. From Big Sable Point light on the eastern coast of Lake Michigan, a vessel sails 191° as indicated on her compass. The variation is 1° E and the deviation is 14° W. What true course has she made good?

Ans. 178°

5. On entering Hampton Roads, Virginia, from seaward, a compass bearing of Cape Henry light is S S E; the compass course at the time is W by S and the deviation is as in Table II. What is the true bearing of the light, and the true course run, the variation being 5° W?

Ans. { True bearing = S 30° E
True course = S 71° W

6. The true course to reach a certain charted buoy from present position is S 8° E; the variation is 2° E, and the deviation according to Table II. What compass course should be steered? Ans. S 23° E

7. After leaving Sand Island light, Lake Superior, a vessel steers by compass N W by W, variation 6° E. Using the deviation in Table II, find the true course made good. Ans. N 67° W

8. The true course between two positions is 131°, the variation 10° W, and the deviation 5° W. Find the compass course. Ans. 146°

9. A power cruiser near Havana, Cuba, steers by compass 280°. Assuming the variation to be 3° E and the deviation 8° E, what is her true course? Ans. 291°

10. If the vessel in the preceding example wishes to establish her position, and finds that the compass bearing of a fixed mark on shore is 163°, what is its corresponding true bearing? Ans. 174°

11. On what course, by her compass, should a power boat be set in order to reach her anchorage, which bears 87° (true) from her present position. The variation and deviation are respectively 13° W and 2° E.

Ans. 98°

MOTOR-BOAT NAVIGATION
(PART 2)

PILOTING

PRELIMINARY REMARKS

1. Among the professional navigators the art of navigation is divided into three branches known, respectively, as *piloting*, *dead reckoning*, and *nautical astronomy*. In deep-sea navigation, the methods of dead reckoning and nautical astronomy are usually carried on together, and independently, in order that one set of calculations may serve as a check on the other and thus lessen the chance or possibility of serious errors. They are essentially practiced when out of sight of land and beyond the range of known objects.

2. Piloting refers to methods of fixing a vessel's position when in sight of land, buoys, lightships, and other aids to navigation. It is the art of conducting a vessel in channels and harbors and along the coasts where landmarks and aids to navigation are available and where the depth of water and dangers to navigation are such as to require constant watch to be kept on the vessel's course. Coast piloting involves the same principles and requires the fixing of the vessel's position continuously as landmarks, lights, beacons, and conspicuous points along the shore are passed. It also includes plotting—courses from one point to another and of keeping a continuous record of the time and distance run on each course in order that the vessel's position may, at any required moment, be shown on the chart.

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3. On any cruise, it should be a fixed rule not to be in doubt of the vessel's position at any time even when entering ports considered safe and easy of access or when traversing waters familiar to the navigator. Whenever an opportunity presents itself to check, by bearings of landmarks, the position deducted from the course and distance run, it should invariably be availed of.

To this end the navigator should be provided with the best and most recent charts of the locality over which the cruise is to be made in addition to Sailing Directions containing descriptions of aids to navigation, corrected up to the time of sailing. The compass, lead, and patent log should be in perfect working order. The deviation of the compass, in particular, should be known for each heading, and properly applied, and no articles of a magnetic character be permitted to remain near the compass to create new errors.

In the following, concise explanations will be given of all methods of practical value by which to navigate a power craft and fix its position. During a cruise strict attention and a close study should be given these methods in order that when put into practice, the navigator may use them with despatch and confidence.

4. Clearing a Dock or Mooring.—Before leaving a dock or mooring care should be taken that everything is ready. The engine should be given a few trial revolutions while the boat is still at the dock, to make sure it will start promptly when the moorings are cast off. If the dock is crowded with boats, a general survey should be made of the best way to get clear without unnecessary bumping into other craft. Fenders should be gotten ready in case it becomes necessary to pass close to other boats. If the boat is not equipped with stationary fenders along the gunwhale, a man with a hand cork fender should stand ready to place it at the proper point of contact between the boats or dock as the case may be.

5. When clearing a dock or landing, it is well not to sheer off the bow too sharply by laying the helm hard over, as at *a*,

Fig. 1, because in so doing, if not sufficiently clear from the dock, the stern of the boat is liable to fetch up heavily against the dock or float, as shown at *b*. It is better to shove off the bow and then start the engine with the helm amidship, as at *c*, when with enough headway the dock or float is readily cleared without trouble. The same methods should also be used when starting from a buoy. If the helm is laid over too soon, the stern is very apt to swing over the buoy and foul the propeller. Due regard should also be given conditions of wind and currents when casting off moorings. Both forces have an important bearing on properly leaving and making a dock or landing. The effect on the rudder and propeller in turning maneuvers are different in nearly every boat built and they should be carefully noted in each individual case.

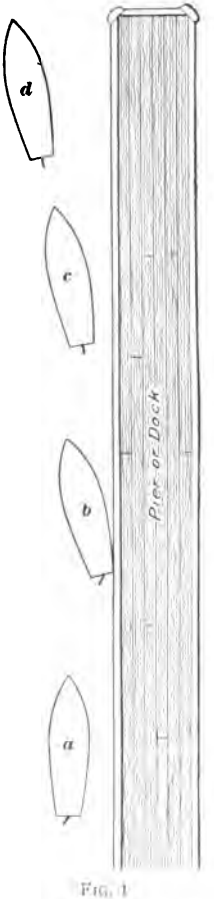

Fig. 1

6. Shaping Courses.—After having cleared the harbor for a trip that includes the run across an open stretch of water, where landmarks and aids to navigation are few and far apart or entirely absent, some definite point of departure should be selected from which to shape the course or courses to be run. The shaping of such courses should be done preferably before starting from the dock, landing, or anchorage by consulting charts and Sailing Directions covering the waters over which the run is to be made.

To shape the course proceed as follows: When the chart is properly spread out, place a parallel ruler between the point selected as starting from, and the first point to be made; move the ruler to the nearest compass rose on the chart until the edge of the ruler rests on the dot in the center of the rose. The intersection of the ruler with the rim of the compass

rose will give the bearing between the two points, or, which is the same thing, the course to be run. If the compass rose on the chart cannot be reached by one step, or move, take as many steps as may be required, provided the parallelism of the first with the last step is preserved. Proceed in a similar manner to find the second, third, and fourth course, etc. Then find the distance to be run on each separate course by using the dividers, selecting a suitable unit from the scale of miles and stepping it off along the course line.

Generally, when courses are laid out, or plotted, on the chart a pencil line is used to connect the points, but it should be very lightly drawn in order that the chart will not be defaced when the line is erased; nor should the dividers prick holes or otherwise mutilate the chart.

7. Illustrative Example.—To illustrate the foregoing assume that a power boat starts from the government pier at Lewes, Delaware, for a cruise in the bay. It is decided to run across the bay to the buoy marking the upper end of the North Shoal and thence through Ricord's Channel, to the southernmost buoy of the Brandywine Shoal. For a point of departure from which to shape the first course run, the light at the eastern terminal of the Delaware breakwater is selected. Placing the parallel ruler between this point *A*, Fig. 2, and the first buoy *B* and then moving the ruler to the compass rose the bearing from *A* to *B* is found to be N 41° E, magnetic. It is then found that in order to make the run through Ricord's Channel a straight course may be taken from the buoy *B* to buoy *C*. The bearing of the latter from the former is N 40° W, according to the compass rose. Again placing the ruler between buoy *C* and *D* at the lower end of the Brandywine Shoal and moving it over the compass rose, as before, the bearing is shown to be N 62° W.

Next, the distance to be run on each course, is found by using the scale of nautical miles at the lower end of the chart. The distance on the first course from *A* to *B* is $9\frac{1}{4}$ miles, the second course from *B* to *C* is slightly over 2 miles; while the distance from *C* to *D* is $4\frac{1}{4}$ miles, making a total run of close to 16

nautical miles. Assuming that no currents, tides, or wind affects the run and that the boat is capable of maintaining a speed of 10 knots, it will require just 1 hour and 36 minutes to complete the run from *A* to *D*.

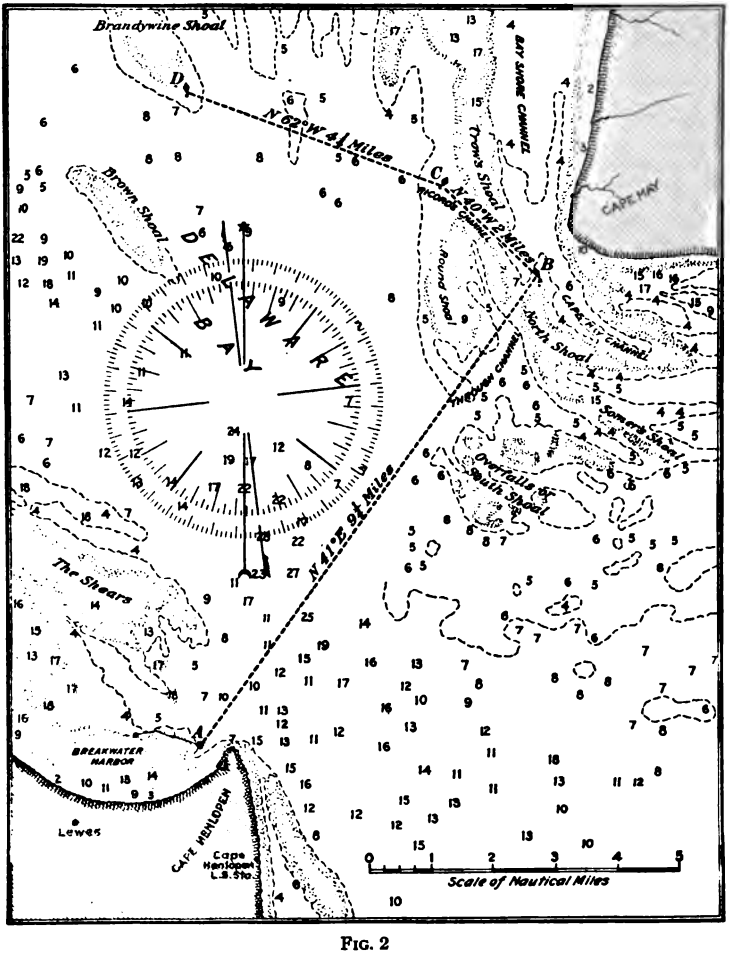

FIG. 2

It will be noticed that the courses given are magnetic, being taken directly from the compass rose which indicates magnetic directions. If the compass on the boat has any deviation,

each course just determined must be corrected, according to the deviation table furnished by the compass adjuster assuming, of course, that the compass is properly compensated.

FIXING POSITIONS

8. Single Bearing and Estimated Distance.—Methods that may be used with advantage in fixing the position of a

FIG. 3

vessel when in sight of land are here given. They should be carefully studied in conjunction with the accompanying charts and illustrations. The method of **single bearing and estimated distance** consists of observing the bearing of some known object, for instance a light, by the compass and then estimating the distance by the eye. The method is

practicable when the distance is small, but as distances measured by the eye, as a rule, are overestimated, probably to the extent of one-fifth or more of the actual distance, this method must not be relied upon when the safety of the ship depends on an accurate knowledge of her position. When only one known object is in sight, the estimated distance should be checked, whenever possible, by sounding.

9. Cross-Bearings.—The method of fixing a position by cross-bearings may be employed whenever two known objects on shore are in sight, provided their position is shown on the chart. When cross-bearings are to be taken, proceed as follows: Remove the hood from the binnacle and sight at each object, in turn, using the right hand as an aid in finding the direction or bearing. Or, better still, if the compass is provided with a sight-bar attachment, place it in position and turn the vanes in the direction of each object, as shown in Fig. 3. The compass point on the card directly underneath the horizontal wire of the sight bar indicates the correct compass bearing of the object. Note each bearing carefully and then proceed to plot both on the chart after having corrected them for deviation due to heading of the boat at the time of observing.

The bearings thus obtained are magnetic bearings and may then be plotted from the magnetic compass rose by placing the parallel ruler on the nearest rose so the edge of the ruler just touches the center point and the requisite degree, or point, on the circumference of the rose. After the ruler is properly placed in the direction of one of the bearings, it should be moved, step by step, until the edge passes through the object; then a pencil line drawn along the edge will represent that bearing and at the time of taking the bearing the boat is somewhere on this line. Then the other bearing is plotted in a similar manner. As the position of the vessel is at some point along this second line also and as the only common point of the two lines is at their point of intersection the position of the vessel on the chart must necessarily be at that point. The establishment of a vessel's position in this manner is known technically as a "fix".

10. The fixing of a position by cross-bearings is illustrated in Fig. 4, where *s a* is the bearing of the object *a* from the boat *s* and *s b* is the bearing of *b* from *s*. The point of intersection *s* of the two lines is the position of the vessel when the bearings were taken. It is evident that the objects selected for cross-bearings should be so situated that the lines of bearing do not intersect at a very acute angle, for the point of intersection in such a case is somewhat doubtful. To obtain good results the angle between the bearings should be about 90° or 8 points and not less than 45°, or 4 points. Whenever it is practical to do so, a sounding should be taken simultaneously with bearings; this will serve as an additional check on the accuracy of the fix.

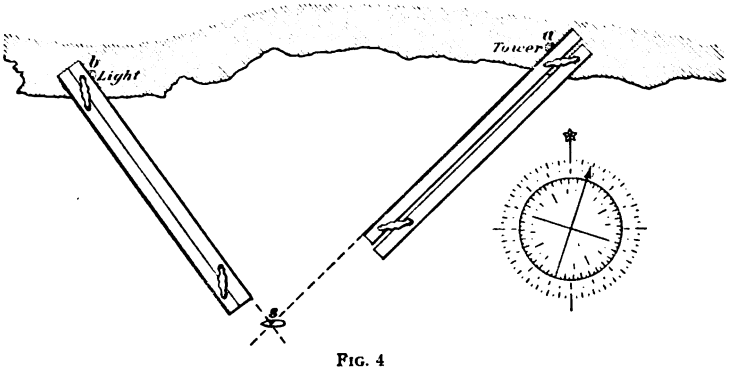

FIG. 4

11. To illustrate the method of cross-bearings by an actual case assume a vessel is coming down the Jersey coast steering S W by S magnetic. When abreast of the Corson life-saving station her estimated distance from the station is $2\frac{3}{4}$ miles; this will fix her position at *a*, Fig. 5. Shortly after leaving her supposed position at *a* in order to verify her position, cross-bearings are taken of the life-saving station house and the Ludlam Beach lighthouse. The station house now bears N 27° W and at the same time the bearing of the lighthouse is S 75° W. Plotting these bearings on the chart, as shown in Fig. 5, they intersect at *c*, which is the actual position of the vessel at the time the cross-bearings are observed. A sounding taken at the same time gives a depth of 7 fathoms, which

agrees with the depth given on the chart at that point; the fix is therefore considered fully reliable. It is therefore evident after plotting the course run, S W by S, through the point *c*, that the actual position of the vessel when abreast of Corson life-saving station was not at *a* but at *b*, and that the distance estimated by eye, $2\frac{3}{4}$ miles, exceeded by more than $\frac{1}{2}$ mile the actual distance. This case shows the value of cross-bearings over the method of a single bearing and estimated distance.

12. The method of cross-bearings is one of the simplest and most reliable used in fixing the position of a vessel, pro-

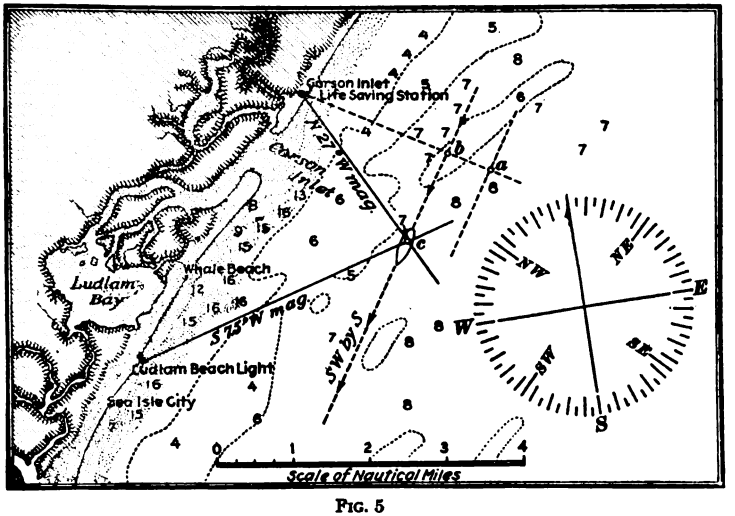

FIG. 5

vided the two bearings are taken so that the angle formed by them is sufficiently large to insure a defined point of intersection. The bearings should be taken in rapid succession and should be properly corrected for any deviation due to heading of vessel that the compass may have. If the chart on which the bearings are plotted is not provided with a magnetic compass rose, the bearings must be corrected for variation of the locality also. But, as a general rule, the compass rose is magnetic and the bearings for this reason need not be corrected for local magnetic variation.

13. Bow-and-Beam Bearings.—In the method of bow-and-beam bearings, a compass bearing is taken of a light, or other prominent known object, when it is 2, 3, or 4 points on the bow, and the time and log noted. A steady, continuous course is then kept and when the bearing has doubled, the log and the time are again noted. (If a patent log is used, it is not necessary to note the time, but simply the register of the log at both bearings.) The distance of the vessel from the object is then equal to the distance run in the interval between the first and second bearings, or the difference of readings of the patent log at the two bearings.

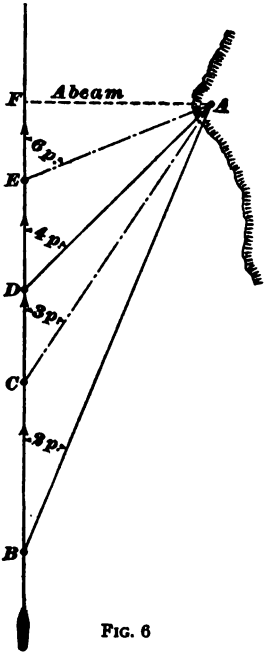

FIG. 6

The reason of this is evident by an inspection of the triangle $B\,D\,A$, Fig. 6. The sum of all angles in a triangle is equal to 180°, or 16 points; the angle at B is 2 points, at D 12 points, and consequently the remaining angle at A must be 2 points. The angles A and B are therefore equal, and hence the sides opposite are equal, or the side $B\,D = D\,A$. In triangle $C\,E\,A$ likewise, the side $C\,E = E\,A$; also, in triangle $D\,F\,A$, the sides $D\,F$ and $F\,A$ are equal, for the same reasons.

14. To find the vessel's position on the chart, it is necessary only to lay off from the object the second bearing, properly corrected, and on this line, from the object, mark the distance run between observations. The point thus obtained will be the position of the vessel.

To illustrate the method, suppose the reading of the patent log when at B, Fig. 6, to be 72.6 miles, and that when at D, or when the bearing is doubled, it indicates 75.8 miles. The distance of the vessel from A is then $75.8 - 72.6 = 3.2$ miles. In other words, $A\,D$ is 3.2 miles long, or equal to the distance run.

15. The bow-and-beam bearings method is frequently used when the vessel is at *D*, Fig. 6, or when the object bears 4 points off the bow; when the bearing has doubled, the vessel is abeam the object, and at a distance equal to *D F*. Hence, the name *four-point bearing*, by which this method is commonly known among navigators. It is preferable, however, to utilize this method of bow bearings when the bearing of the object is 2 or 3 points off the bow; then, when either bearing is doubled, the position of the vessel is fixed before the object is abeam, which

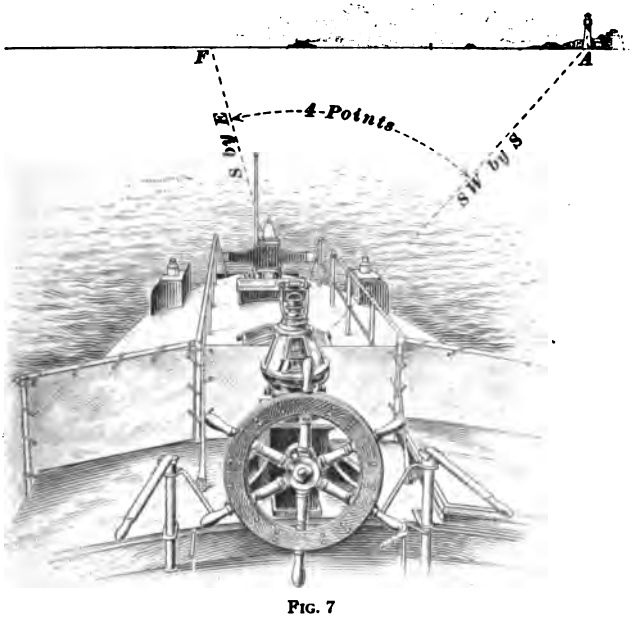

FIG. 7

insures safety should rocks or other obstacles be located abeam, or outside of the object.

The four-point bearing is perhaps better illustrated in Fig. 7, which represents a view taken on board a power boat having a lighthouse in sight on the starboard bow. The course steered by the boat is S by E. Hence, when the light bears S W by S, or when the angle *F D A* is four points, the reading of the log is noted. When the light is abeam, or when its bearing by compass is W by S, the log is again read. The distance *D F*

run between the bearings is then equal to FA, the distance of the boat from the lighthouse, provided no current or tide has interfered with the run.

16. When using bow-and-beam bearings with 2 and 4 points, the distance $F\,A$, Fig. 6, when abeam, is readily found by multiplying the distance run $B\,D\,(=D\,A)$ by .71 or, as is done in practice, by .7. Thus, if $B\,D$ is equal to 5 miles, $D\,F$ and $F\,A$ will be, respectively, $5\times.7=3.5$ miles. This will enable the navigator to know beforehand how far off the object he will be when abeam, assuming that the same course is steered. If, therefore, rocks or shoals should happen to be situated outside the object they are easily avoided by changing the course. The distance when abeam is equal, also, to the distance run between bearings, taken at $26\frac{1}{2}°$ and 45°, respectively; but the former method of multiplying the distance run from 2 to 4 points by *seven-tenths* is preferable, being simpler, and more readily committed to memory.

17. It should be noticed that this method is applicable, also, after the vessel has passed the object. In such a case, the first observed angle on the stern should be twice the second angle. Thus, if the angle between the object and the vessel's stern is 4 points, the second angle, or bearing, should be noted when the object bears 2 points. The distance run between the bearings, or readings, of the patent log is then equal to the distance of the vessel from the object when it bore 4 points.

NOTE.—When practicing bow bearings, it is well to remember that in this method, as well as in any other method of coast navigation where the speed of the yacht is involved, due allowance must be made for any current or tide that is known to affect the yacht's run.

18. Two Bearings of Same Object.—It is evident that the foregoing method is subject to certain restrictions. The observer must wait and watch until the angle on the bow has doubled, or, if the vessel has passed the object, until the angle on the stern is just one-half the first bearing. These inconveniences, involving considerable time and attention, are eliminated in the following method. A compass bearing is taken of some known object at any instant, and the number of points

contained between this bearing and the vessel's head, or course, is noted. A straight, continuous course is then kept until the bearing of the object has altered at least 3 points, when another bearing is taken and the number of points between it and the vessel's head is again noted. The manner of finding the position from these data is illustrated by the following example: Assume the true bearing of an object A, Fig. 8, to be N 53° W and the true course steered to be N 3° W. After a distance of 4.5 miles is covered, according to the patent log, a second bearing of the same object is found to be S 50° W; find the yacht's position.

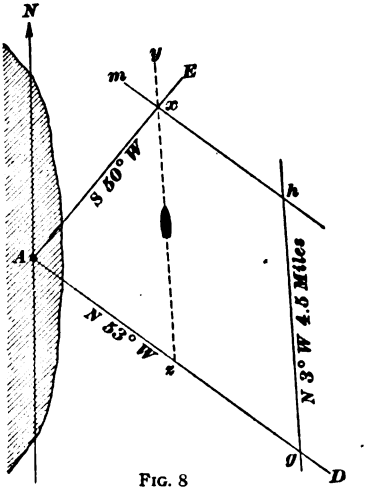

FIG. 8

19. Solution by Plotting. On the chart, lay off, by means of parallel rulers, from the object A, Fig. 8, the two bearings $A\ E$ and $A\ D$, and draw a line $g\ h$ in the direction of the yacht's course (= N 3° W) so that it intersects the first bearing $A\ D$ (it does not matter where). On this line, lay off from the intersecting point g, the distance run in the interval, according to scale of chart, and from the point h thus obtained draw a line $h\ m$ parallel to the first bearing. The point x at which this line intersects the second bearing $A\ E$ will be the position of the yacht at the time of the second observation, and by drawing from x a line $x\ z$ parallel to the yacht's course $g\ h$, the point of intersection z of that line with the first bearing $A\ D$ will show the position of the yacht at the instant the first bearing was taken. The position at both bearings is thus quickly and conveniently fixed.

20. Solution by Table.—Instead of plotting the bearings on the chart as described, the distances may be found, perhaps more conveniently, by using Table I in the following manner: Find the angle, in points, between the first bearing

and the vessel's course and that between the second bearing and the vessel's course. Enter the table with the first number of points in the top row of figures and the second number of points in the extreme left-hand side column of figures, and take out the corresponding number that is under the former and opposite the latter; multiply this by the number of miles run in the interval. The product is the distance, in nautical miles, at the time the *second* bearing was taken.

Referring to Fig. 8, the angle $A\ Z\ x$ between the vessel's head and the first bearing is equal to 50°, or $4\frac{1}{2}$ points, nearly; the angle $A\ x\ y$ at the second bearing is equal to $A\ x\ m + m\ x\ y$, or $77° + 50° = 127°$, or $11\frac{1}{4}$ points, nearly. Now, under $4\frac{1}{2}$ in the top row of Table I and opposite $11\frac{1}{4}$ in the side column will be found the number .80. Multiplying this by the distance run in the interval will give the distance of the vessel, in miles, from A to her position at the second bearing; thus, $4.5 \times .8 = 3.6$.

To find the distance $A\ z$ of the vessel from the object at the first bearing, enter the same table with the supplement of the angle at the second bearing in the top row and the supplement of the angle at the first bearing in the side column; take out the corresponding number and multiply by the distance run. The product will be the distance of the vessel from the object at the instant of the first bearing.

21. When making use of this method it is well to bear in mind that bearings containing less than 3 points between the first time of bearing and the course run must not be taken in the event of this angle being less than 3 points; the table cannot be used for finding the position when the first bearing is taken because the supplement of the angle than exceeds 13 points, which is the limit of the table.

22. Another illustration of this method is given in Fig. 9, which represents the entrance to the Potomac River and part of Chesapeake Bay. When going down the Potomac River steering S E by E (magnetic), it is decided to fix the position of the yacht accurately before leaving Point Lookout. When the light bore east, magnetic, the register of the patent log indicated 175.5 miles; when the bearing of the light had changed

to N by E the log read 178.75, making a total distance run between bearings of $178.75-175.5=3.25$ or $3\frac{1}{4}$ miles.

23. To find, by plotting, the distance of the yacht from Point Lookout light at the time of the second bearing or when the light bore N by E proceed as follows: Plot the respective bearings as shown and from any point *a* on the first bearing draw a line *a b* in the direction of the course run S E by E. On this line, lay off from *a* the distance run, $3\frac{1}{4}$ miles, according to the scale of nautical miles found on the chart. At the extremity *b* of this distance draw a second line *b c* parallel to

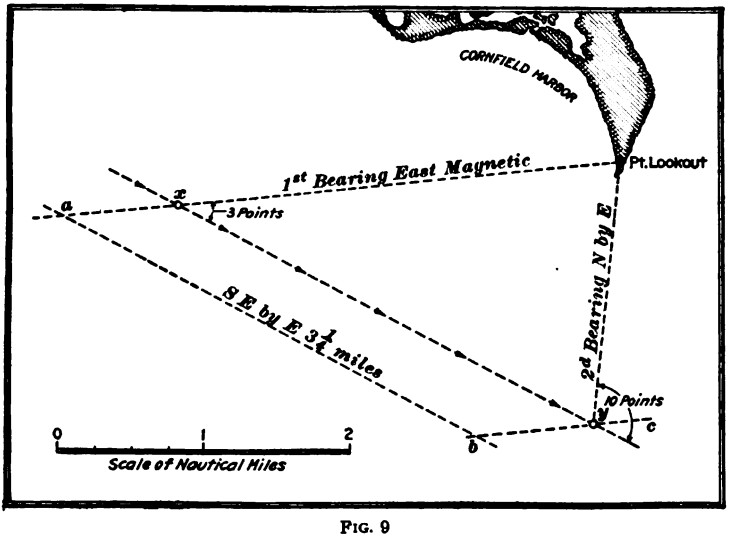

FIG. 9

the first line of bearing; the point *y* where this line intersects the second bearing is the position of the yacht at the time of observing the second bearing of the light. To find the place where the first bearing was taken draw a line from *y* parallel with the course run. The intersection *x* of this line with the first bearing will show the position of the yacht at that time.

The same result will be obtained by using Table I. Thus, the angle between the course and the first bearing is 3 points; the angle between the second bearing and the course is 10 points. Entering the Table with 3 at the top and 10 in

TABLE I

DISTANCE OF AN OBJECT BY TWO BEARINGS AND DISTANCE RUN

Difference Between the Course and the Second Bearing in Points.	Difference Between the Course and the First Bearing in Points.																		
	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	6¼
	Factors to be Taken																	
4	1.00																	
4¼	.90	1.12																
4½	.81	1.00	1.23															
4¾	.74	.91	1.10	1.34														
5	.69	.83	1.00	1.20	1.45													
5¼	.64	.77	.92	1.09	1.30	1.56												
5½	.60	.72	.85	1.00	1.18	1.39	1.66											
5¾	.57	.67	.79	.93	1.08	1.26	1.48	1.75										
6	.54	.64	.74	.86	1.00	1.16	1.35	1.57	1.85									
6¼	.52	.60	.70	.81	.93	1.07	1.23	1.42	1.65	1.94								
6½	.50	.58	.67	.77	.88	1.00	1.14	1.31	1.50	1.73	2.02							
6¾	.48	.55	.64	.73	.83	.94	1.06	1.21	1.38	1.57	1.81	2.10						
7	.46	.53	.61	.69	.79	.89	1.00	1.13	1.27	1.44	1.64	1.88	2.17					
7¼	.45	.51	.59	.67	.75	.84	.94	1.06	1.19	1.33	1.50	1.70	1.94	2.24				
7½	.43	.50	.57	.64	.72	.80	.90	1.00	1.11	1.24	1.39	1.56	1.76	2.01	2.30			
7¾	.42	.48	.55	.62	.69	.77	.86	.95	1.05	1.17	1.30	1.45	1.62	1.82	2.06	2.36		
8	.41	.47	.53	.60	.67	.74	.82	.91	1.00	1.10	1.22	1.35	1.50	1.67	1.87	2.11	2.41	
8¼	.41	.46	.52	.58	.65	.72	.79	.87	.95	1.05	1.15	1.27	1.40	1.54	1.72	1.92	2.16	2.46
8½	.40	.45	.51	.57	.63	.69	.76	.84	.91	1.00	1.09	1.20	1.31	1.44	1.59	1.76	1.96	2.20
8¾	.39	.45	.50	.56	.61	.68	.74	.81	.88	.96	1.04	1.14	1.24	1.35	1.48	1.63	1.80	2.00
9	.39	.44	.49	.55	.60	.66	.72	.78	.85	.92	1.00	1.08	1.18	1.28	1.39	1.52	1.66	1.83
9¼	.39	.44	.49	.54	.59	.64	.70	.76	.82	.89	.96	1.04	1.12	1.21	1.31	1.42	1.55	1.69
9½	.38	.43	.48	.53	.58	.63	.69	.74	.80	.86	.93	1.00	1.08	1.16	1.25	1.35	1.46	1.58
9¾	.38	.43	.48	.52	.57	.62	.67	.73	.78	.84	.90	.97	1.04	1.11	1.19	1.28	1.38	1.48
10	.38	.43	.47	.52	.57	.61	.66	.71	.77	.82	.88	.94	1.00	1.07	1.14	1.22	1.31	1.40
10¼	.38	.43	.47	.52	.56	.61	.65	.70	.75	.80	.86	.91	.97	1.03	1.10	1.17	1.25	1.33
10½	.38	.43	.47	.51	.56	.60	.65	.69	.74	.79	.84	.89	.94	1.00	1.06	1.13	1.20	1.27
10¾	.39	.43	.47	.51	.56	.60	.64	.68	.73	.77	.82	.87	.92	.97	1.03	1.00	1.15	1.22
11	.39	.43	.47	.51	.56	.60	.64	.68	.72	.76	.81	.85	.90	.95	1.00	1.05	1.11	1.17
11¼	.39	.44	.48	.52	.56	.60	.64	.67	.71	.76	.80	.84	.88	.93	.98	1.03	1.08	1.13
11½	.40	.44	.48	.52	.56	.60	.63	.67	.71	.75	.79	.83	.87	.91	.95	1.00	1.05	1.10
11¾	.41	.45	.49	.52	.56	.60	.64	.67	.71	.74	.78	.82	.86	.90	.94	.98	1.02	1.07
12	.41	.45	.49	.53	.57	.60	.64	.67	.71	.74	.78	.81	.85	.88	.92	.96	1.00	1.04
12¼	.42	.46	.50	.54	.57	.61	.64	.67	.71	.74	.77	.81	.84	.87	.91	.94	.98	1.02
12½	.43	.47	.51	.55	.58	.61	.65	.68	.71	.74	.77	.80	.84	.87	.90	.93	.97	1.00
12¾	.45	.48	.52	.56	.59	.62	.65	.68	.71	.74	.77	.80	.83	.86	.89	.92	.95	.98
13	.46	.49	.53	.57	.60	.62	.66	.68	.71	.73	.75	.79	.83	.86	.88	.91	.94	.96

the side column the corresponding factor is .57; multiplying this number by the distance run between bearings the product $3.25 \times .57 = 1.85$ is the distance, in miles, of the yacht from the light when second bearing was taken.

24. To find the distance of the yacht from the light when the first bearing was taken Table I may be entered with the supplements of both angles. The supplement of the angle at y is $16 - 10 = 6$ points; that of x is $16 - 3 = 13$ points. Using the former in the top row and the latter in the side column the corresponding number is .94, which, when multiplied by the distance run, 3.25 miles, will give the distance of the point x or the yacht's position when the light bore East, as $3.25 \times .94 = 3.06$ miles. The correctness of both distances may be verified by the actual measurements, using the scale given

TABLE I—(*Continued*)

Difference Between the Course and the First Bearing in Points																			
Difference Between the Course and the Second Bearing in Points	6¼	6½	7	7¼	7½	7¾	8	8¼	8½	8¾	9	9¼	9½	9¾	10	10¼	10½	10¾
	Factors to be Taken																	
8¼	2.50																	
8½	2.24	2.53																
9	2.03	2.27	2.56															
9¼	1.86	2.06	2.29	2.58														
9½	1.72	1.89	2.08	2.31	2.60													
9¾	1.61	1.75	1.91	2.10	2.33	2.61												
10	1.51	1.63	1.77	1.92	2.11	2.34	2.61											
10¼	1.42	1.53	1.65	1.78	1.94	2.12	2.34	2.61										
10½	1.35	1.44	1.55	1.66	1.79	1.94	2.12	2.34	2.60									
10¾	1.29	1.37	1.46	1.56	1.67	1.80	1.95	2.12	2.33	2.58								
11	1.24	1.31	1.39	1.47	1.57	1.68	1.80	1.94	2.11	2.31	2.56							
11¼	1.19	1.25	1.32	1.40	1.48	1.57	1.68	1.80	1.94	2.10	2.29	2.53						
11½	1.15	1.21	1.27	1.34	1.41	1.49	1.58	1.68	1.79	1.92	2.08	2.27	2.50					
11¾	1.12	1.17	1.22	1.28	1.34	1.41	1.49	1.57	1.67	1.78	1.91	2.06	2.24	2.46				
12	1.09	1.13	1.18	1.23	1.29	1.35	1.41	1.49	1.57	1.66	1.77	1.89	2.03	2.20	2.41			
12¼	1.06	1.10	1.14	1.19	1.24	1.29	1.35	1.41	1.48	1.56	1.65	1.75	1.86	2.00	2.16	2.36		
12½	1.04	1.07	1.11	1.15	1.20	1.24	1.29	1.35	1.41	1.47	1.55	1.63	1.72	1.83	1.96	2.11	2.30	
12¾	1.02	1.05	1.08	1.12	1.16	1.20	1.25	1.29	1.34	1.40	1.46	1.53	1.61	1.69	1.80	1.92	2.06	2.24
13	1.00	1.03	1.06	1.09	1.13	1.16	1.20	1.24	1.29	1.33	1.40	1.45	1.51	1.58	1.66	1.76	1.87	2.01

on chart, Fig. 9. It will be noticed in this case that if the first bearing had been taken earlier the first angle at x would have been less than 3 points and consequently the supplement greater than 13 points which would place it beyond the limits of the table. As a matter of fact, the position at first bearing is

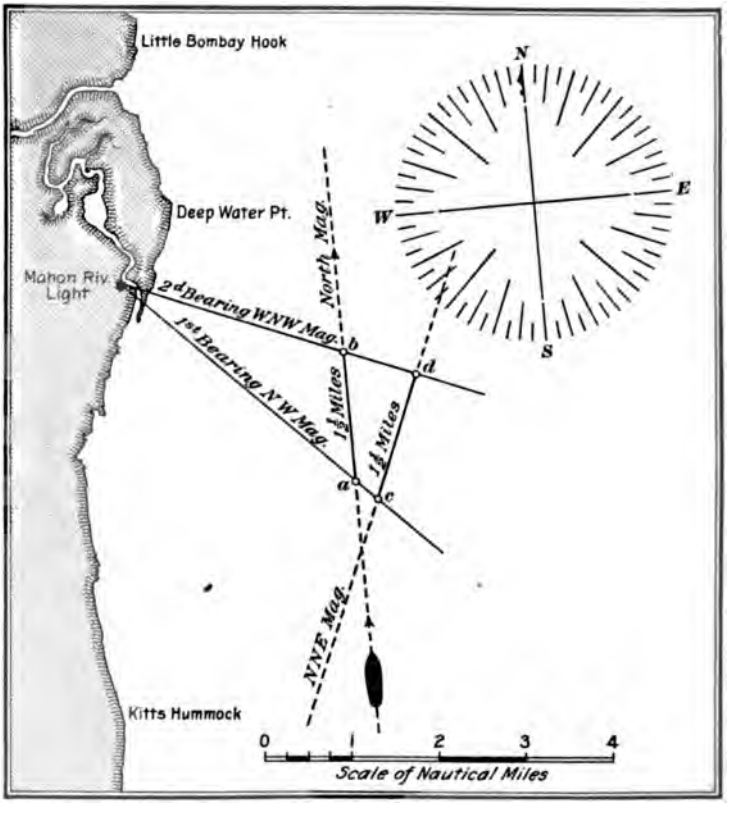

FIG. 10

seldom if ever required. In practice only the second bearing is plotted on the chart and the distance found by calculation, as already explained, is laid off from the object establishing the point y. From this point the course to be run is then shaped to the next point it is desired to reach.

25. Briefly stated, the method by two bearings of the same object and distance run may be summarized as follows: Note number of points between course and first bearing and course and second bearing; also distance run. Find from Table I the corresponding factor and calculate the distance. On the second line of bearing, lay off this distance from object and mark with a pencil the position thus fixed by a small circle.

26. Simplification of Method.—A simpler though less accurate application of the two-bearing method is as follows: Take the bearing of an object at any time, then run a steady course for a distance of say 1, 1½, or 2 miles and note bearing of object when the distance selected is completed. Lay off the two bearings on the chart as usual and mark on a strip of paper the distance run according to the scale on the chart. From the nearest compass rose carry forwards the course run and place the strip of paper parallel with the edge of the ruler and find by trial where the distance just spans the two bearings. The point where it touches the second bearing is the position when that bearing was taken.

Suppose, for example, that a yacht is in sight of Mahon River light, Fig. 10, steering north, magnetic. When the light bears N W the log and time is noted; after running 1½ miles on this course the light bears W N W. To fix the position of

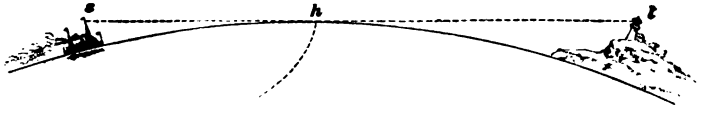

FIG. 11

the yacht, plot the two bearings on the chart, as shown, and mark on the edge of a strip of paper the distance run; slip the strip in between the two lines of bearing keeping it parallel with the course run. When correctly adjusted, it will span the two lines at *a* and *b*, the latter point representing the position when the second bearing was taken. If the course run had been N N E, the points *c* and *d* would represent, respectively, the position of the yacht when first and second bearings were taken, which may be verified by actual measurements on

the chart. In place of using the edge of a strip of paper for marking the distance run, a pair of dividers may be employed provided the position of the legs are maintained intact during the operation.

27. To Find Distance From Known Fixed Objects Seen on Sea Horizon.—The method of determining the distance of a vessel from an object seen on the sea horizon depends

TABLE II

DISTANCES OF OBJECTS AT SEA, IN NAUTICAL MILES

Height Feet	Distance Nautical Miles	Height Feet	Distance Nautical Miles	Height Feet	Distance Nautical Miles	Height Feet	Distance Nautical Miles	Height Feet	Distance Nautical Miles	Height Feet	Distance Nautical Miles
1	1.15	35	6.81	69	9.55	115	12.34	285	19.41	510	25.97
2	1.63	36	6.90	70	9.62	120	12.60	290	19.57	520	26.22
3	1.99	37	7.00	71	9.69	125	12.86	295	19.75	530	26.47
4	2.30	38	7.09	72	9.76	130	13.12	300	19.92	540	26.73
5	2.57	39	7.18	73	9.83	135	13.37	305	20.08	550	26.97
6	2.81	40	7.27	74	9.89	140	13.62	310	20.24	560	27.22
7	3.04	41	7.36	75	9.96	145	13.85	315	20.40	570	27.46
8	3.25	42	7.45	76	10.03	150	14.08	320	20.57	580	27.70
9	3.45	43	7.54	77	10.09	155	14.32	325	20.73	590	27.94
10	3.63	44	7.63	78	10.16	160	14.55	330	20.88	600	28.17
11	3.81	45	7.71	79	10.22	165	14.77	335	21.04	610	28.41
12	3.99	46	7.80	80	10.28	170	14.99	340	21.20	620	28.64
13	4.15	47	7.88	81	10.35	175	15.21	345	21.35	630	28.87
14	4.31	48	7.97	82	10.41	180	15.43	350	21.51	640	29.10
15	4.46	49	8.05	83	10.48	185	15.64	355	21.67	650	29.32
16	4.60	50	8.13	84	10.54	190	15.85	360	21.82	660	29.55
17	4.75	51	8.21	85	10.60	195	16.06	365	21.97	670	29.77
18	4.88	52	8.30	86	10.66	200	16.26	370	22.12	680	29.99
19	5.02	53	8.37	87	10.73	205	16.46	375	22.27	690	30.21
20	5.15	54	8.45	88	10.79	210	16.66	380	22.42	700	30.43
21	5.27	55	8.53	89	10.85	215	16.86	385	22.56	710	30.64
22	5.40	56	8.61	90	10.91	220	17.05	390	22.71	720	30.86
23	5.52	57	8.68	91	10.97	225	17.25	395	22.86	730	31.07
24	5.64	58	8.76	92	11.03	230	17.44	400	23.00	740	31.28
25	5.75	59	8.83	93	11.09	235	17.63	410	23.29	750	31.49
26	5.87	60	8.91	94	11.15	240	17.81	420	23.57	760	31.70
27	5.98	61	8.98	95	11.21	245	18.00	430	23.85	770	31.91
28	6.09	62	9.06	96	11.27	250	18.18	440	24.12	780	32.12
29	6.20	63	9.13	97	11.33	255	18.36	450	24.39	790	32.32
30	6.30	64	9.20	98	11.39	260	18.54	460	24.66	800	32.53
31	6.41	65	9.27	99	11.44	265	18.72	470	24.93	850	33.52
32	6.51	66	9.34	100	11.50	270	18.89	480	25.19	900	34.50
33	6.61	67	9.41	105	11.79	275	19.07	490	25.45	950	35.45
34	6.71	68	9.48	110	12.07	280	19.24	500	25.71	1,000	36.36

on the uniform curvature of the sea, in consequence of which all terrestrial objects appear or disappear from sight at certain distances from the observer.

In order to get a clear conception of this method, let *l*, Fig. 11, represent a lighthouse situated on the summit of a mountain, *s* the lookout stationed at the masthead of an approaching vessel, and *h* the visible horizon of *s*. As soon as the top of the lighthouse appears above the horizon, it is evident that the distance of the vessel from the light is equal to the sum of the distances *s h* and *h l*. These distances, depending on the heights of *s* and *l*, are recorded in Tables II and III, which give the maximum distance at which an object is visible at sea according to its elevation and that of the observer, the weather

TABLE III

DISTANCES OF OBJECTS AT SEA, IN STATUTE MILES

Height Feet	Distance Statute Miles	Height Feet	Distance Statute Miles	Height Feet	Distance Statute Miles	Height Feet	Distance Statute Miles	Height Feet	Distance Statute Miles	Height Feet	Distance Statute Miles
1	1.32	26	6.72	55	9.77	210	19.09	460	28.25	920	39.95
2	1.86	27	6.84	60	10.20	220	19.53	470	28.55	940	40.38
3	2.28	28	6.97	65	10.62	230	19.97	480	28.85	960	40.81
4	2.63	29	7.09	70	11.02	240	20.40	490	29.15	980	41.23
5	2.94	30	7.21	75	11.40	250	20.82	500	29.45	1,000	41.65
6	3.23	31	7.33	80	11.78	260	21.24	520	30.03	1,100	43.68
7	3.48	32	7.45	85	12.14	270	21.64	540	30.60	1,200	45.62
8	3.73	33	7.57	90	12.49	280	22.04	560	31.17	1,300	47.48
9	3.95	34	7.68	95	12.84	290	22.43	580	31.72	1,400	49.28
10	4.16	35	7.79	100	13.17	300	22.81	600	32.26	1,500	51.01
11	4.37	36	7.90	105	13.50	310	23.19	620	32.79	1,600	52.68
12	4.56	37	8.01	110	13.81	320	23.56	640	33.32	1,700	54.30
13	4.75	38	8.12	115	14.12	330	23.92	660	33.83	1,800	55.88
14	4.93	39	8.22	120	14.43	340	24.28	680	34.34	1,900	57.41
15	5.10	40	8.33	125	14.72	350	24.64	700	34.84	2,000	58.90
16	5.27	41	8.43	130	15.02	360	24.99	720	35.34	2,100	60.35
17	5.43	42	8.54	135	15.30	370	25.33	740	35.83	2,200	61.77
18	5.59	43	8.64	140	15.58	380	25.67	760	36.31	2,300	63.16
19	5.74	44	8.74	145	15.86	390	26.01	780	36.78	2,400	64.52
20	5.89	45	8.33	150	16.13	400	26.34	800	37.25	2,500	65.85
21	6.03	46	8.93	160	16.66	410	26.67	820	37.71	2,600	67.15
22	6.18	47	9.03	170	17.17	420	26.99	840	38.17	2,700	68.43
23	6.32	48	9.12	180	17.67	430	27.31	860	38.62	2,800	69.69
24	6.45	49	9.22	190	18.15	440	27.63	880	39.07	2,900	70.92
25	6.59	50	9.31	200	18.63	450	27.94	900	39.51	3,000	72.13

being clear and the refraction normal. One of these tables gives the distances in nautical and the other in statute miles.

Assume, for instance, that the height of the lighthouse above the level of the sea is 140 feet and that of the observer on the bridge 16 feet; what will be the distance of the ship from *l*, expressed in nautical miles, at the moment the top of the lighthouse appears on the horizon? Consulting Table II, it will be found that for a height of 140 feet the corresponding distance is 13.62 miles, and for a height of 16 feet the distance of the visible horizon is 4.60 miles. Therefore, the distance of the vessel from the lighthouse must be equal to the sum of these distances, or $13.62+4.60=18.22$ miles.

EXAMPLE 1.—The top of Cape Henlopen lighthouse is seen on the horizon. Assuming the height of the observer's eye above the water-line to be 9 feet, and the height of the lighthouse to be 125 feet, according to Table of Lights, what is the distance of the observer from the light expressed, respectively, in nautical and in statute miles?

SOLUTION.—Entering Tables II and III it is found that the distance corresponding to height of

9 ft. = 3.4 naut. mi., or 3.9 stat. mi.
125 ft. = 12.8 naut. mi., or 14.7 stat. mi.

Hence, distance = 16.2 naut. mi., or 18.6 stat. mi. Ans.

EXAMPLE 2.—A yacht is bound for Havana from Key West. At the time expected to get within sight of the lighthouse on Morro Castle at the entrance to Havana harbor a man is sent up the masthead to look for the light. His height above the water-line is 19 feet. The height of the top of the lighthouse is 144 feet. What is the distance of the yacht from the light when it appears on the horizon?

SOLUTION.—Consulting Tables II and III the distance corresponding to height of

19 ft. = 5.0 naut. mi. or, 5.7 stat. mi.
144 ft. = 13.8 naut. mi. or, 15.8 stat. mi.

Hence, distance = 18.8 naut. mi., or 21.5 stat. mi. Ans.

28. This method of finding the distance of a known object when it appears or disappears on the sea horizon is very useful at night in clear weather when coming within, or going out of, the range of visibility of a light the height of which is known. It must be remembered, however, that the visibility of lights as recorded on Charts or in the Table of Lights is that

distance corresponding to an elevation of the eye of 15 feet; hence, when the observer is at a greater or less height than 15 feet above the water-line of his vessel, the actual elevation of his eye should be used to enter the table and calculate the distance, as previously shown, instead of using the recorded distance of visibility of the light.

To make this clear take the Barnegat light. The height of this lighthouse, according to the Table of Lights,* is 164 feet and its recorded distance of visibility 19 miles. According to Table II, the distance corresponding to

164 feet = 14.7 nautical miles
15 feet (height of eye) = 4.4 nautical miles
Distance visible = 19.1 nautical miles

In other words, the adding of distance of visibility for 15 feet to that for height of object will give the distance of visibility recorded in the Table of Lights. If the height of the eye is less or greater than 15 feet use the actual height to the nearest foot to find the distance of visibility in the manner just explained.

SAFETY BEARINGS

29. Bearings that by virtue of their direction may serve as a boundary between dangerous and navigable waters are known as **safety bearings**; they are of especial value in navigating between and in keeping clear of submerged reefs and shoal water. In the utilization of such bearings, much depends, of course, on the locality and on the charted objects in sight that may be used for the establishment of such bearings.

An illustration that will serve to show the usefulness of such bearings is given in Fig. 12. Suppose a power boat is going up the bay near Bluff Point. In order to reach her destination she has to keep in the middle of the channel shown, which is unbuoyed. Safety bearings are accordingly established, one running E N E from Bluff Point, another running north to lighthouse shown on the southern promontory of Goat Island, and finally a third running N E by E from Bluff Point to guide

*United States Coast Pilot, Atlantic Coast, Part V.

the boat into the last bend of the channel. A glance at the chart will now show that as soon as the point *c* is reached the course run should be E N E until the lighthouse on Goat Island bears north, when the course is changed to that point. Then,

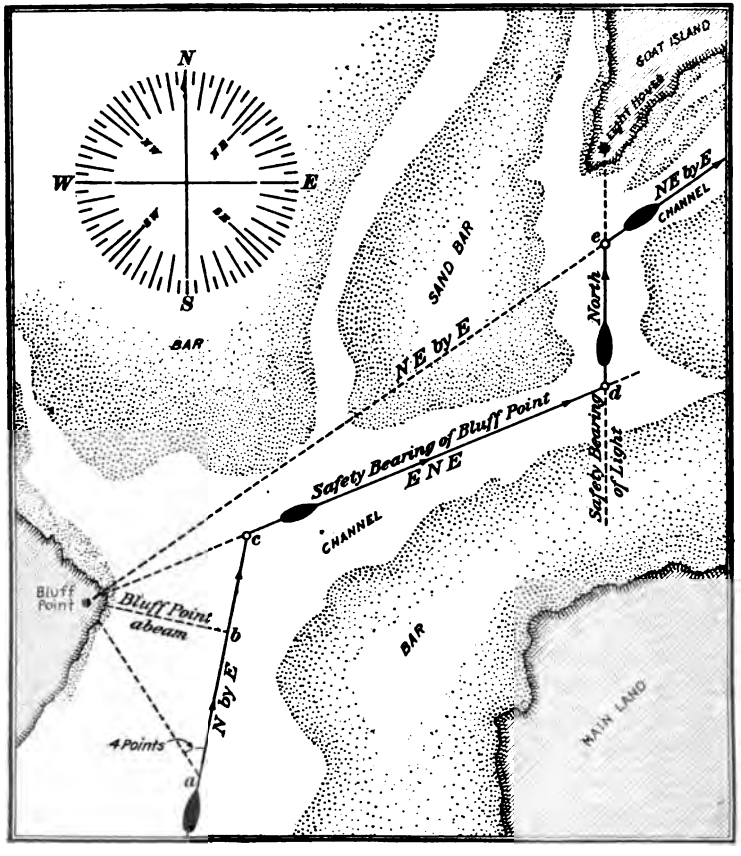

FIG. 12

when Bluff Point bears S W by W the course is again changed to N E by E. As long as these courses are strictly kept, the boat may safely pass through the channel.

30. To establish the exact position of the boat before entering the channel proper, it is well to employ one of the methods

already explained, such as the four-point bearing when at *a*. Readings are taken of the patent log when Bluff Point bears 4 points on the bow and again when it is abeam, which fixes her position at *b*. The same course N by E is now kept until Bluff Point bears W S W, when her position is at *c*. Here the course is changed to E N E and the boat kept on that course until the lighthouse on Goat Island bears north. Running directly for the light a close watch is kept on Bluff Point until its bearing has changed to S W by W when the course is changed to N E by E, as shown.

This case illustrates how bearings of different objects in sight can be utilized in navigating an unbuoyed channel. It is evident, however, that before an attempt is made to enter a channel the bearings must be carefully plotted on the chart.

SEXTANT ANGLES

31. It is also possible to fix the position of a yacht by methods in which a sextant or similar instrument is used to measure the angles formed by the observer and objects visible on shore. On small motor boats, the employment of a sextant for navigating purposes may be out of the question; but on large seagoing power yachts, the sextant will be found a valuable adjunct to the navigating officer. Practice in the manipulation of the sextant in measuring angles, both horizontal and vertical, is therefore strongly advocated. Hortizonal angles measured by a sextant are unquestionably more reliable than compass bearings because they involve no such uncertain element as deviation, though they require conspicuous and accurately charted objects that are separated by large and favorable angles.

32. To Find Distance From Base of Bluff or Lighthouse of Known Height.—When the base of a known object such as a lighthouse is visible its height *h*, Fig. 13, above the surface of the sea may be considered as one of the perpendiculars in a right triangle, and the distance *d* of the yacht from the object as the other perpendicular, *v* being the angle subtended

by the lighthouse as seen and measured on board the yacht. To find the distance d, measure the angle v and look up the exact height of the lighthouse above sea level as recorded in

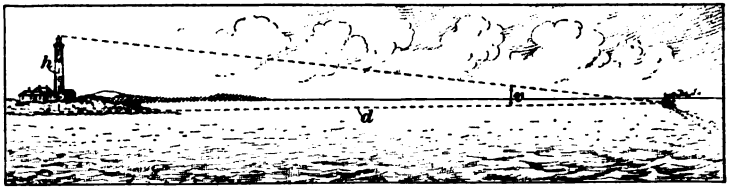

FIG. 13

the Table of Lights. Then use the following formula, when the distance is to be expressed in nautical miles

$$d = \frac{.57\,h}{v}$$

or, this formula when the distance is expressed in statute miles

$$d = \frac{.65\,h}{v}$$

For convenience, this operation may be expressed in the following rule which is readily committed to memory:

Rule.—*Measure, with a sextant, or other instrument of reflection, the angle subtended by the top and base of the object in sight; this will give the value of v. Divide the height of the object by the number of minutes in the angle and multiply the quotient by .57 or .65, according to the mile, nautical or statute, used. The result is the required distance.*

EXAMPLE 1.—The angle subtended by a lighthouse 144 feet high is found to be 13′; find the distance expressed in both nautical and statute miles.

SOLUTION.—In this case, $v = 13'$ and $h = 144$. Applying the rule just given, the distance

$$\left.\begin{aligned} d &= \frac{.57\,h}{v} = \frac{.57 \times 144}{13} = 6.3 \text{ naut. mi.} \\ d &= \frac{.65\,h}{v} = \frac{.65 \times 144}{13} = 7.2 \text{ stat. mi.} \end{aligned}\right\} \text{Ans.}$$

EXAMPLE 2.—The angle subtended by the lighthouse on Hog Island, to the north of Great Machipongo Inlet, Virginia, was measured by a

sextant and found to be 10′ 30″; the height of the light above the sea level is 180 feet. What is the distance of the ship from the light, expressed in nautical miles?

SOLUTION.—In this case, $v = 10' 30'' = 10.5'$, and $h = 180$. Hence,

$$d = \frac{.57 \times 180}{10.5} = 9.8 \text{ naut. mi.} \quad \text{Ans.}$$

33. Cautionary Remarks.—The method of locating the distance of a vessel from a known object by means of sextant angles should be utilized only when the distance is rather short and when the base of the selected object is distinctly seen. It should be borne in mind, also, that the distance obtained by this method is that of the vessel from a point vertically below the observed object, and not that from the shore line (see Fig. 13). In cases where the lighthouse or other selected object stands at a distance inland, or above the water level, the angle measured will be the one subtended by the top of the object and the shore line. This angle, however, owing to the height of the eye, is greater than the required one, which is supposed to be at the water-line of the vessel, and as a greater angle corresponds to a shorter distance, the actual position of the vessel will be farther off shore than the result by the method indicates. Owing to the interference of terrestrial refraction, which causes objects near the horizon to appear higher than they actually are, the result by this method should be considered only an approximation. The heights of lights above mean high water, expressed in feet, are to be found in the List of Lights and Fog Signals of the United States and in the Table of Lights published in the United States Coast Pilot.*

The method may prove useful, however, under various circumstances. For instance, when compelled to anchor during a fog an occasional or partial lift of the fog may enable a navigator to measure the height of some known object, such as a lighthouse, a bluff, or a cliff that happens to become visible, and this together with its bearing affords a convenient means of approximately fixing the position of the vessel.

*Both publications may be procured on application to the Bureau of Lighthouses, Washington, District of Columbia.

DANGER ANGLE

34. The danger angle, which is either horizontal or vertical, is a method that may be used with advantage in rounding or passing points along a coast line outside of which some hidden obstacle is located, such as rocks, shoals, sunken derelicts, partly or wholly covered by water, and which cannot readily be seen except at close quarters. Such obstructions, when their position is known, may be passed at any desired distance by utilizing the methods about to be described.

35. Horizontal Danger Angle.—The method known as the horizontal danger angle is an application of one of the geometrical properties of the circle; namely, that angles inscribed in the same segment are equal. The following illustration will serve to explain the method:

Suppose that when passing along a coast it is deemed advisable to avoid some hidden rocks R, Fig. 14, by passing $\frac{1}{2}$ mile outside of them. On the shore, there are two known objects in sight, a lighthouse L and a church C, both being marked on the chart. Then, to find the danger angle corresponding to a distance of $\frac{1}{2}$ mile from the rocks, proceed as follows: With the outermost rock as a center and a radius equal to $\frac{1}{2}$ mile, describe a circle on the chart. Then, through the most seaward point a of this circle and the points C and L, describe another circle; connect a with C and L; measure with a protractor the angle $C\,a\,L$ formed by the lines $a\,C$ and $a\,L$; assume it to be 52°, as in the figure. This is the required horizontal danger angle. Now, set that angle on the sextant and watch the two selected objects C and L, holding the instrument in a horizontal position. When the two objects appear in the horizon glass, the yacht is close to the *circle of safety* $a_1\,a\,a_2$; and when they come in contact, the yacht is *on* that circle; once on the circle, change the course so that the two images will remain in contact until the danger is passed. So long as this is being done, the yacht will be on the circle of safety $a_1\,a\,a_2$, since the angles $C\,a_1\,L$, $C\,a\,L$, and $C\,a_2\,L$ are all equal, being angles in the same segment. If the angle increases, the yacht is on the

inside of the circle of safety and consequently nearer the danger than is desirable; if it becomes smaller, the yacht is outside of the ½-mile limit. However, by watching the angle closely and changing the course accordingly, one cannot fail to keep at the required distance from the rocks.

In this method it will be noted that two objects, separated by a favorable angle, are necessary. When only one object is

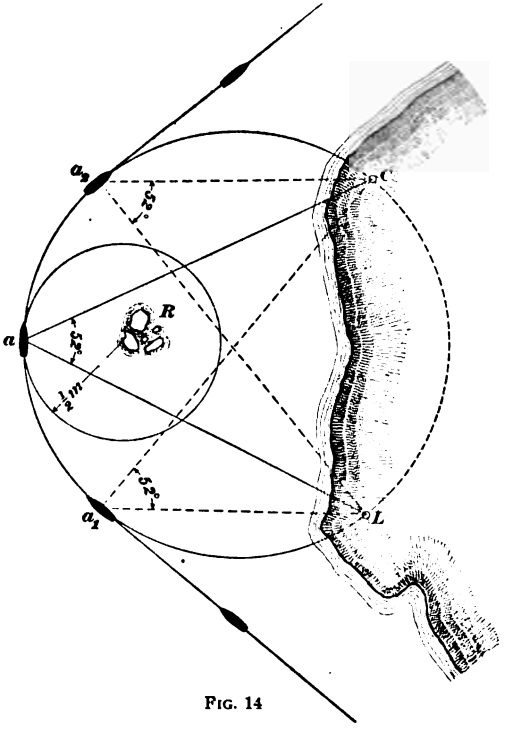

FIG. 14

in sight, the vertical danger-angle method may be used, provided the object is sufficiently high to subtend a reasonably distinct angle, which can be measured by the navigator.

36. Vertical Danger Angle.—The method known as the vertical danger angle is based on the principle that the distance to an object will remain the same as long as the angle subtended by the height of the object remains the same. Tables

containing angles corresponding to different heights and distances, expressed in miles and fractions of a mile, have accordingly been prepared for the use of navigators.

Among such tables may be mentioned Captain Lecky's "Danger Angle and Off-Shore Distance Tables," and the tables of vertical danger angles found in Captain Patterson's "Navigator's Pocketbook." If no tables are available, the required vertical angle is readily found by the following formula:

$$v = \frac{.57\,h}{d}$$

in which h = height of object, in feet;
d = distance, in miles;
v = required angle, in minutes of arc.

This formula is expressed in the form of a rule, as follows:

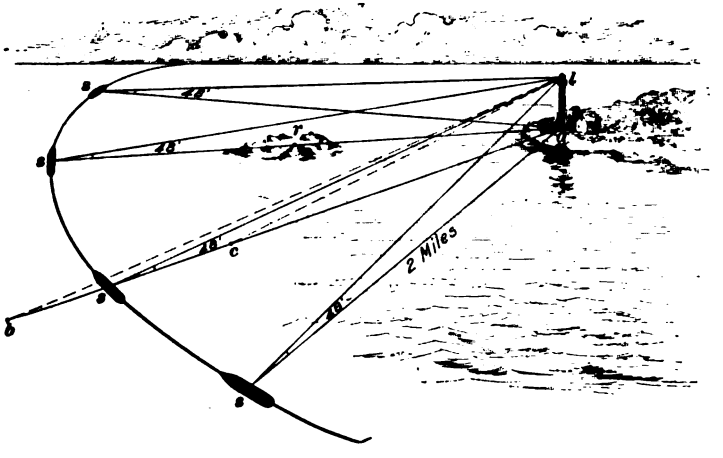

FIG. 15

Rule.—*Multiply height of object, in feet, by .57; the product divided by the distance, in miles, will give the vertical angle expressed in minutes of arc.*

The value of the angle obtained by this rule is approximate only, though it is correct to the nearest minute of arc, which for all practical purposes is sufficiently close.

37. The method of using the vertical danger angle is best shown by an illustration: Assume that a vessel is about to round a point of land, Fig. 15, on which is standing a lighthouse *l* the tower of which is 170 feet high. Outside the point and within a mile of the lighthouse lie a number of rocks *r* immediately below the surface of the sea; because awash, they cannot be seen but their position is indicated on the chart. It is desired to avoid these rocks by passing 1 mile outside of them, or, what is the same thing, by passing 2 miles outside of the lighthouse. In order to do this it is necessary to know what angle the lighthouse will subtend at a distance of 2 miles; in other words, the vertical danger angle for that distance must be known. To determine this angle enter a table of Vertical Danger Angles, a reproduction of which is here given, with 170 feet at the top and 2 miles in the distance column, when

Distance in Miles and Tenths	Vertical Danger Angles					
	170 Feet	175 Feet	180 Feet	185 Feet	190 Feet	195 Feet
1.9	50′ 35″	52′ 4″	53′ 34″	55′ 3″	56′ 32″	58′ 1″
2.0	48′ 3″	49′ 28″	50′ 53″	52′ 18″	53′ 43″	55′ 7″
2.1	45′ 46″	47′ 7″	48′ 28″	49′ 49″	51′ 9″	52′ 30″

directly below the former and opposite the latter is found 48′ 3″, which is the angle the lighthouse should subtend at a distance of 2 miles. Applying the rule given the same result is obtained; or,

$$v = \frac{.57 \times 170}{2} = \frac{96.9}{2} = 48.4'$$

All that has to be done now is to set the sextant to an angle of 48′ and go ahead, keeping the course so that the angle will remain the same until the obstruction is passed. So long as the angle *l s a* between the top of the lighthouse *l* and the waterline *s a* is 48′ the vessel is at the correct distance; if the angle becomes less, the vessel is outside of the 2-mile limit, as at *b*; if the angle becomes greater, the vessel is nearer the rocks than desired, as at *c*. That such must be the case is evident from the fact that the angle *l s a* is greater than *l b a*, but smaller

than *l c a*, and of course the greater the angle becomes the shorter will be the distance. It is not necessary to move the index bar of the sextant at all, simply have it clamped at the required angle; for, if the object *l* rises above the water-line *s a*, as seen in the horizon glass of the instrument, the angle is larger than that set and the vessel is nearer the rocks than is desirable; if the object *l* drops below the water-line, the angle is smaller and the vessel is consequently outside of her intended course.

38. When observing vertical danger angles, it is advisable that the observer be as near to the surface of the water as possible; this will tend to minimize the error caused by the height of the observer's eye above the water-line. This error, however, will increase the angle, and as a greater angle corresponds to a shorter distance the vessel will actually be farther from the danger than the recorded distance and thus be in a safer position, unless a second danger lies outside and close to the track of the course run.

The method by horizontal and vertical danger angles should prove useful in cases where buoys and marks indicating the location of shoals and rocks have been destroyed or carried away by ice or otherwise. When circumstances permit the selection of either a vertical or a horizontal danger angle, the latter should always be preferred as being much more accurate than the former; primarily on account of the horizontal angle being much larger than the vertical angle and secondly, because the vertical angle subtended by the height of lights and other objects on shore cannot always be observed with accuracy. It is evident, also, that the horizontal danger angle may be used during both night and day, whenever two lights are in sight, whereas, the use of the vertical danger angle is limited to the day only.

39. It must be remembered that before either of these methods is used in the actual practice of navigating a vessel past a danger, a person should be efficient in their use. It is foolhardy to experiment in places where actual danger exists. Practice should at first be had with imaginary dangers until a

person is sure that he is able to utilize the methods with ease and confidence.

40. Application of Horizontal Danger Angle. Assume that a good-sized power yacht is going up the New Jersey coast from Cape May bound for a rendezvous off Stone Harbor, Fig. 16. Information has been received that a schooner

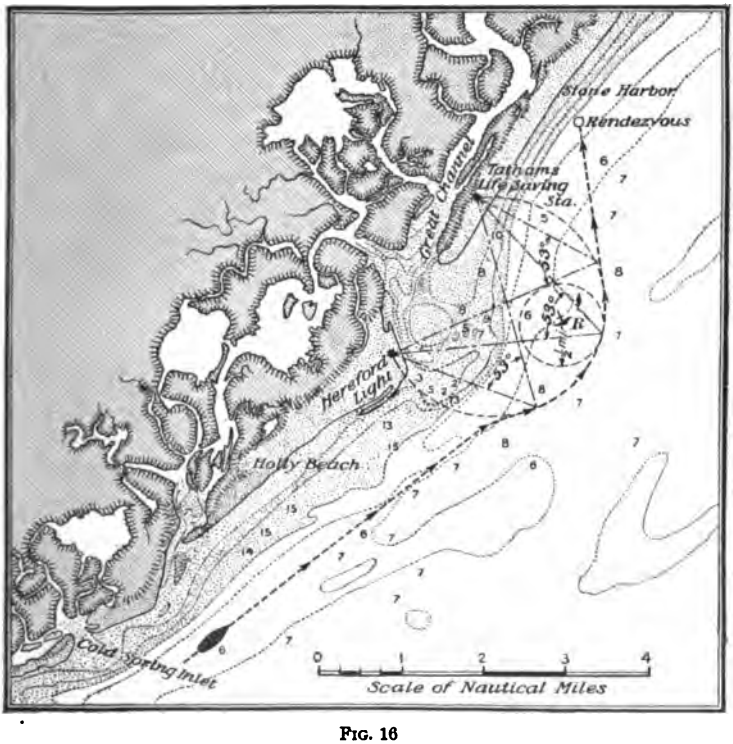

FIG. 16

has sunk outside of Hereford Inlet and lies in 6 fathoms of water about ¼ mile southwest of the bell buoy anchored off the inlet. But the buoy that has been used as a marker for the wreck has been carried away and cannot be used longer as a guide in avoiding the derelict. It is not deemed advisable to take chances of passing between the wreck and the shoal water extending for a considerable distance outside the inlet, since

at high tide the wreck is totally submerged. On the shore, there are two conspicuous marks, the Hereford lighthouse, and the building of the Tathams life-saving station, that can be used in forming a horizontal danger angle in rounding the wreck R at say $\frac{1}{2}$ mile distance.

To find the angle that the two objects should subtend, proceed as follows: With R as a center and $\frac{1}{2}$ nautical mile taken from the scale of the chart used, describe a circle as shown in Fig. 16; connect the most seaward point of that circle with the two objects on shore by drawing light pencil lines. The angle formed by these lines is the required horizontal danger angle and when measured, by means of a protractor, will be found to contain 53°. By setting the sextant to that angle and keeping the objects in contact, as already explained, the wreck may be rounded at the required distance.

NAVIGATING IN A FOG

41. In foggy weather, the most important aid to navigation is the lead and the lead line, with a reliable chart on which an adequate number of soundings are shown with characteristics of the bottom. To power boats in particular is the lead useful because they navigate almost exclusively in waters the depth of which is easily sounded. Soundings taken at random are of little or no value in fixing or checking the position of a vessel. A record must be kept of the interval and the distance run between each cast and the lead or sounding machine must be kept going continuously and systematically. If this is done a vessel may proceed with almost as much safety in a fog as in clear weather, provided currents do not seriously interfere with the run. And even in the case of currents affecting the vessel, their effect may be determined by a systematic use of soundings.

42. When a fog has settled down and indications point to continued thick weather, bring the lead and line from its locker and have the lead snugly armed with tallow, in readiness for sounding. Then running at a moderate speed, consistent with

prevailing and local conditions take several casts with the lead at regular intervals, say every 5, 10 or 15 minutes, and at each cast note the time, the course, and the distance run between each cast; examine also after each cast the arming of the lead to find what kind of bottom it has touched. Write down this data on a piece of paper. After a sufficient number of casts have been made, rule a line *a b*, Fig. 17, on a piece of tracing cloth to represent the direction of the meridian (north-and-south line) and another line *c d* to represent the course, or courses, steered. On this line *c d* lay off and mark down, according to the scale of the chart embracing the locality being navigated, the distance run between each cast, and at each point thus obtained, mark the respective soundings and character of the bottom, as shown in Fig. 17. The result will be a *line* or *chain of soundings*.

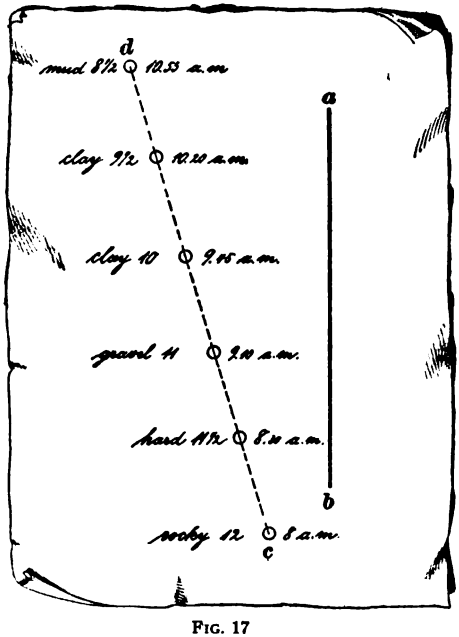

FIG. 17

When this has been done, place the tracing cloth on the chart with the point *c* of the course line on the place where it is thought the boat was when the first cast was taken and keep the line *a b* parallel with the meridians on the chart. If the soundings agree with depths printed on the chart, as seen through the tracing cloth, the position of the vessel is fixed at once; but if they do not agree move the tracing cloth, keeping the line *a b* parallel with the meridians, until a place is found where they do agree. The point on the chart underneath *d* is then the position where the last sounding was taken.

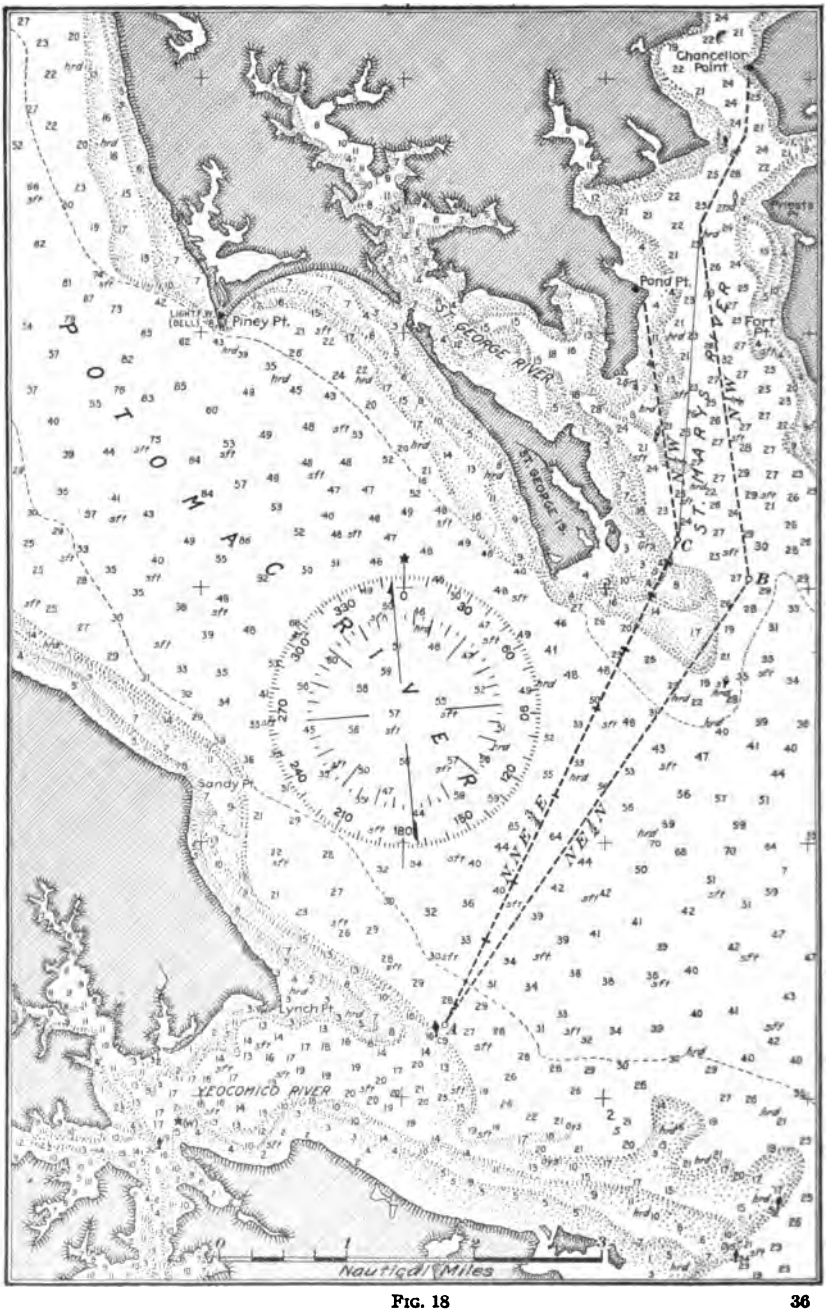
Chancellor Point
Pond Pt.
Fort Pt.
Piney Pt.
LIGHT PT. (BELL)
ST. GEORGE RIVER
ST. GEORGE'S I.
POTOMAC
RIVER
Sandy Pt.
Lynch Pt.
YEOCOMICO RIVER
NAVIGABLE CHANNEL
A
B
C
Nautical Miles

FIG. 18

43. In cases where there is reason to suspect that the run has been affected by an unknown current or by a tide of uncertain velocity and direction, the line *a b*, representing the direction of the meridian may not be parallel with meridians on the chart when the line of sounding has been shifted to agree with the printed soundings. In such cases, the navigator should be guided by the soundings, regardless of the direction in which they run when placed so as to agree with soundings printed on the chart.

44. To illustrate the usefulness of systematic soundings in cases where the vessel is affected by a tide or current, assume that a power boat is going out of the Yeocomico River bound for Chancellor Point in the St. Mary's River. When close to the buoy marking the entrance to the Yeocomico River a dense fog with rain settles down. As the sea is smooth and the draft of the boat only 3 feet, it is decided to make the run. When overtaken by the fog the position is at *A*, Fig. 18. From this point the course is laid out N E ½ N (magnetic) in order to clear at a distance of about ¼ mile the shallow bars extending S E of St. George Island. As the boat proceeds along this course soundings are taken after each of the following distances have been covered:

Distances	Depth	Bottom
¾ mile	33 feet	Mud
½ mile	41 feet	Mud
¾ mile	64 feet	Coarse sand
¾ mile	51 feet	Coarse sand
½ mile	23 feet	Coarse sand
½ mile	11 feet	Hard
¼ mile	5 feet	Hard
¼ mile	22 feet	Coarse sand

The distances and soundings being plotted on a piece of tracing cloth (according to the scale of nautical miles found on the chart), the sheet is spread out on the chart. According to the course run, and the distance covered, 4¼ miles, the position of the yacht should be at *B*; but the plotted soundings do

not agree with those on the chart along that direction. The tracing cloth is accordingly moved, and after a few shiftings it will be found that the soundings printed along the line *A C* coincide most nearly with those recorded by the lead. The actual position of the yacht must consequently be at *C*, or about ¾ mile out of her supposed position. An unknown current or tide setting northward has evidently affected the run to the extent shown.

45. It will be noticed that if these series of soundings had not been taken; if dependence had been placed entirely on the compass and log the actual position would not have been discovered in the fog. Without soundings to check the run, it would be natural for the navigator to assume his position to be at *B* at the time the last cast was taken. At this point the course would be changed to N ¼ W heading up the St. Mary's River, and if that course had been kept up under the assumption of the change of course taking place at *B* instead of at *C* it would in due time land the yacht somewhere in the vicinity of Pond Point. By the information gained through the soundings, establishing the position of the yacht at *C*, the course may be changed to about N by E to avoid Pond Point and make Chancelor Point.

When utilizing this method of serial soundings, an exact agreement of depths recorded by the lead and those given on the chart should not always be expected, as there may be slight inaccuracies in reading off the lead line, especially when moving at some speed; or the tide may cause discrepancies, or the chart itself may lack perfection; but in a general way, the soundings and the characteristics of the bottom should agree and make the fix a reliable one. If a very marked discrepancy is shown, with less water than expected, it should cause the navigator to proceed with more than usual caution.

46. Sounding Curves.—On all charts issued by the government, in addition to giving the depth expressed in feet or fathoms, there will be found dotted curves, or lines connecting points of equal depth; these are technically known as *sounding curves*. In foggy weather, excellent use may be made of the

lead, or the sounding machine, by following such a curve of sounding along a coast where the curves run with any degree of regularity. The vessel can be kept very closely and with perfect safety on any such curve by heading out and in as the depths decrease or increase.

During a fog, an unbouyed channel may be navigated in a similar manner by using the lead or sounding machine, running a slightly zig-zig course from one side of the channel to the other, the course being changed whenever the water is found shoaling sufficiently to warrant going no further to that side. It is better to side the channel in this way than attempt to

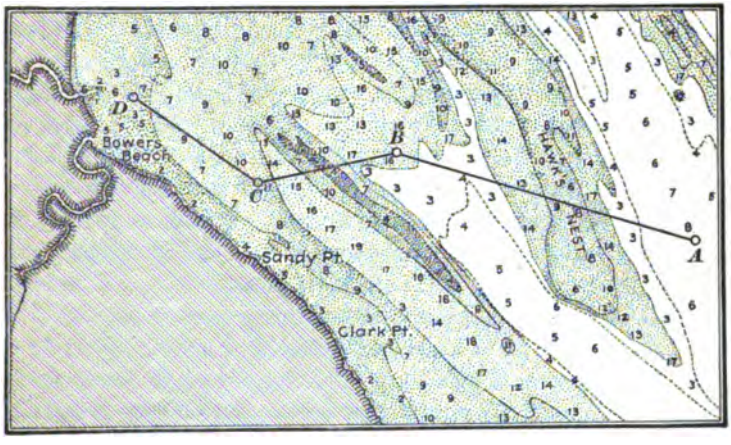

FIG. 19

follow it directly, because in the latter case, when the water begins to shoal dangerously, it may not be possible to tell on which side of the channel the vessel happens to be.

47. Entering Ports, Etc., in Fog.—When attempting to approach and enter a port, river, or sound in foggy weather, an examination of the chart may often reveal an exceptional and peculiar formation of the bottom that will be very useful in reaching a conclusion as to the advisability of going ahead. A case in point is shown in Fig. 19, where the position of the vessel bound for Bowers Beach is assumed to be at *A*. In her position with 8 fathoms of water she may now proceed along

the line shown, getting 8 and 9 feet of water on Hawk's Nest; then as the depth increases, after passing over the deep spot of 4 fathoms, the course may be changed at *B* in the direction shown, crossing a shallow bar of 4 feet. When soundings show 10 and 11 feet, as at *C*, the course may again be changed in the direction *C D*. Along this course the depth will decrease gradually and uniformly until at *D* the 6-foot sounding will indicate the boat's position to be within 1 mile of Bowers Beach. In this manner a vessel may feel its way in a fog being guided by the depths and changing its course whenever it is considered expedient to do so.

48. Fog Signals.—Generally speaking, there are two classes of fog signals; those made by vessels to indicate their position to others for the purpose of avoiding collision and those made by shore stations to give warning of danger to approaching or passing vessels. The fog-signal apparatus at shore stations on the coasts of the United States consists of five different types as follows: Steam whistles of ordinary type of large size, steam sirens and sirens operated by compressed air, Daboll trumpets, Bells struck by machinery, and Whistling buoys and bell buoys operated by the action of the sea and wind, or by clockwork impelled by weight or spring.

The buoys are placed on outlying dangers or at entrances to channels. Nearly all lighthouses are equipped with a whistle, siren, trumpet, or bell that are operated in foggy weather according to a prearranged system, which enables one station to be distinguished from another. The particular signal given at each station is found in the List of Lights and Fog Signals and in the United States Coast Pilot.

Recently a system of submarine signals has been established at a number of points along the coast by which sound signals are transmitted through water enabling a vessel, equipped with apparatus to receive such signals, to locate within a compass point its bearing from the station where the signal is given; and, also, to detect the presence in a fog of other vessels operating submarine bells. More than 50 submarine bells of all types are operated along the coast lines of the United States.

49. Audibility of Fog Signals.—In clear, still weather, steam whistles from shore stations should be heard at a distance of from 3 to 5 miles, bells from 1 to 3 miles, and sirens up to 20 and 25 miles. A ship's steam whistle should be heard not less than 2 miles, a fog horn and bell not less than 1 mile. But so many and so seemingly erratic are the atmospheric conditions that modify the audibility of sound that no reliance can be placed in hearing the signals at the distances mentioned. Therefore, when attempting to navigate a boat by the sound from fog signals great caution must be exercised. Experiments have proved that such signals are subject to capricious deflections due to wind and atmospheric conditions. A sound signal that is heard at a certain distance may be entirely lost when the vessel hearing it approaches the place from which it is sounded; and again the signal is often inaudible at distances where it ought to be heard. Apparently there are certain areas in the fog bank, known as *zones of silence*, that possess the property of diverting or entirely arresting the sound waves. In addition to these causes, fog signals are sometimes not heard when expected because the fog bank may not embrace the locality where the signal is stationed, though it may surround a boat. A fog often creeps toward the shore from seawards and is not observed by the lighthouse attendants until upon them; consequently, the fog signals are not sounded and the navigator of a fog-bound vessel thinks he is not within range of the signal.

50. One of the difficulties with fog signals is that the direction from whence they come cannot be determined with any accuracy. Hence, to locate the position of a vessel by means of fog signals is out of question. Again, fog signals given by a passing steamer are often mistaken for those issued by a shore signal station, and the phenomenon of echo frequently plays pranks with the judgment of the navigator in trying to fix in his mind the direction from which the sound comes. A number of vessels have been wrecked by taking the echo of a fog signal for the original sound. The echo of a sound may be produced with startling similarity when sound waves strike the sail of a ship, a steamer's hull, or the side of a cliff.

Taking into consideration all of these facts it is evident that caution must prevail when navigating by the aid of fog signals sent through air. In a fog, the lead is generally the only safe guide and should be faithfully used.

Submarine signals on the other hand are not subject to interference by the wind, freaks of echoes, and other noises as is the case with sound signals sent through the atmosphere, but are practically uniform, radiating in all directions from the submerged bell. The range of submarine bells varies from 5 to 6 miles but have been heard at even greater distances. The locations of stations operating submarine bells and characteristics of signals are given in the Coast Pilots.

ALLOWANCE FOR CURRENTS

51. A **current** may be defined as a large volume of water, or a portion of the sea, which is kept in motion by the wind or by some other cause or causes. The direction of a current or the point of the compass toward which it flows is called the *set* of the current; and its velocity or rate is called the *drift* and oftentimes *rate*. The mode adopted when speaking of the direction of a wind, which is named according to the point from which it blows, is thus reversed when speaking of the direction of a current. Hence, a current setting toward the north is called a northerly current and a current setting toward the east is called an easterly current.

52. Briefly stated, the phenomenon of **tide** is the periodical and alternate rise and fall of the water level, as seen from sea beaches, cliffs, etc. When the water rises to the highest point it is capable of reaching on any particular day, it is called *high water* or *high tide;* when it sinks to the lowest corresponding point, it is said to be *low water* or *low tide*. High tides follow each other at intervals of 12 hours and 25 minutes. Low tides succeed each other at the same intervals.

Tides do not always rise to the same height, but every fortnight after new and full moons they rise much higher than in the alternate weeks, or after the first and last quarters of the

moon. These high tides are called *spring tides*, and the lower ones *neap tides*.

During the first and third quarters of the lunar month, the sun's influence tends to draw the tide to the westward of its position under the influence of the moon, and so tends to hasten the time of high water; this is called *priming*. During the second and fourth quarters the sun has an opposite effect, and tends to delay the time of high water, thus causing what is known as *lagging*.

Slack water is the interval of time when the tide has reached its lowest or its highest point and has not yet commenced to rise or recede.

The term *set* applies to tides as well as to currents, and indicates the direction toward which the tide or current is flowing. The *force*, or *strength*, of a tide or current is its rate of movement, usually expressed in knots.

The *range* of a tide is the vertical distance between the high and low water of any tide.

The *age* of a tide is the interval between the time of new or full moon and the succeeding spring tide.

53. Tide Tables.—The time of high and low water for any port along the seaboard of the United States may be conveniently found from the Tide Tables or Tide Books published annually by the United States Coast and Geodetic Survey and also by private concerns. In such books the time and range of tides at all principal ports are predicted for every day of the year. Full instructions for using the tables are usually given in the books.

In the United States Coast Pilot, published in five sections by the Coast and Geodetic Survey, will be found also current tables giving the set and rate of currents caused by tides in the principal fairways along the coast. These tables, in connection with other tidal data given, are most useful in determining the effect of currents.

54. Effect of Currents.—When navigating a power yacht in waters where tides and currents prevail due allowance must be made for the effect of such currents. During the day and

in clear weather with known landmarks in sight, this is comparatively easy. The vessel is then headed against the tide or current at a sufficient angle that her track through water will lead directly to the point in sight that it is required to reach. Thus, in Fig. 20, if the current is running in the direction of the arrows and a power yacht is bound for the point *b* from *a*, the bow is headed toward the current enough to counteract its effect. If set on a course directly heading for *b*, the yacht will be unable to make that point owing to the effect of the current, and will probably be set along the dotted line toward *c*, depending, of course, on speed of yacht and the strength of the current. In cases where no objects are in sight, and particularly at night or in a fog, allowance must be made for currents when shaping a course. If the direction and force of the current are known, this may be done as follows:

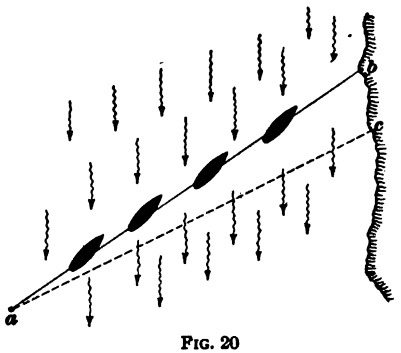

FIG. 20

55. Current Diagrams.—It is essential to state that whenever a body is acted upon by two forces of sufficient strength to move the body, the direction of motion will be intermediate of the directions in which the two forces act. To make this clear, assume that a body at *A*. Fig. 21, is acted

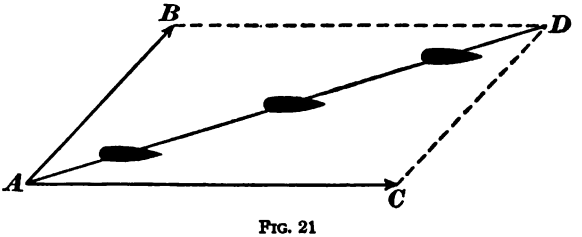

FIG. 21

on, at the same instant, by two forces represented in directions and force by the straight lines *A B* and *A C*, respectively.

Then, the resultant or combined effect of these forces will be represented in velocity and direction by the diagonal AD of the parallelogram having $A\ B$ and $A\ C$ as adjacent sides.

Applying this explanation to a case of current sailing, it will be seen that if a vessel at A, Fig. 21, is able to cover the distance from A to C in 1 hour, and, if in the same interval of time, a current is flowing from A to B, at the close of the hour the vessel will be neither at B or C, but at D, having been moved by her own propelling force and that of the current along the diagonal $A\ D$, as indicated in the figure. The result is precisely the same as though the vessel had first gone from A to C without being influenced by the current, then stopped, and traveled from C to D with the current only. Hence, AD will represent the actual course and distance made good by the vessel.

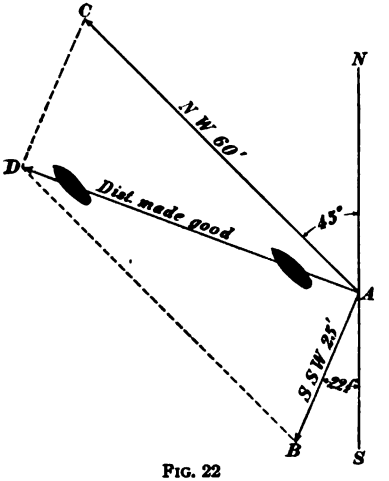

FIG. 22

56. From the foregoing, it is evident that when the set and drift of a current, or tide, are known and a record has been kept of the course and distance run by the yacht, the course and distance made good can be readily found by plotting the direction of the run with that of the current. This is done by completing the parallelogram and drawing the diagonal, which will then represent the actual course and distance run over ground.

EXAMPLE 1.—A power yacht running N W, magnetic, has covered a distance of 60 miles. During the same interval of time she has been influenced by a current that sets magnetic S S W 25 miles. Find the course and distance made good.

SOLUTION.—Referring to Fig. 22, draw on a suitable sheet of paper a line $N\ S$ to represent the direction of the magnetic meridian; then from any point A draw $A\ C$ = N W = N 45° W, and make this line 60 mi., according to an assumed scale. From the same point A draw $A\ B$ = S S W

= S 22° 30′ W, and lay off on it from *A*, according to the same scale, a distance of 25 mi. The two lines *A C* and *A B* will then represent, respectively, the course and distance run, and the set and drift of the current. Now complete the parallelogram *A B D C* by drawing *B D* parallel to *A C* and *C D* parallel to *A B*; then join *A* and *D*. The diagonal *A D* is then the course made good, and its length measured on the same scale as *A C* and *A B* is the distance made good. Using a protractor, it will be found that the course made good, or the angle *N A D*, is N 69½° W and the distance 55½ mi., nearly. Ans.

57. When the bearing of the port is taken from the chart and the directions and rate of the prevailing current are known, the course to steer to counteract the effect may be found in a similar manner by plotting the directions, using the bearing of the port as the diagonal in the parallelogram constructed. The following examples will illustrate this case:

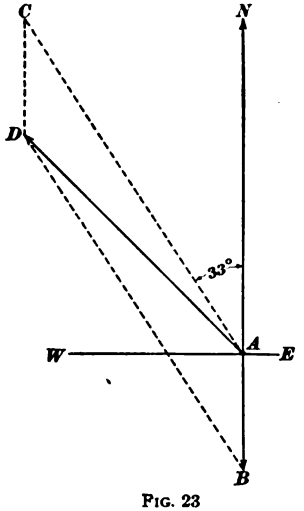

FIG. 23

EXAMPLE 1.—Assume that a power yacht is bound for a point, the bearing of which according to chart is N W, or N 45° W, and that it is considered advisable not to exceed a speed of 8 knots. The chart shows that a steady current is running in a southerly direction at a rate of 3 miles an hour. Find what course should be steered in order to counteract the effect of the current.

SOLUTION.—From *A*, on the meridian *N B*, Fig 23, draw *A D* = N 45° W, and make it in length equal to the number of miles the yacht will make in 1 hr., or 8 mi. Then draw *A B* to represent the set and drift of the current, or = south, 3 mi., using the same assumed scale. With *A D* as a diagonal, construct the parallelogram *A B D C*; the line *A C* will then represent the direction in which to steer to counteract the effect of the current. Measuring the angle *N A C*, the course thus indicated is found to be N 33° W. Ans.

EXAMPLE 2.—A power boat making a speed of 8 miles an hour is about to make the run from Race Rock light station to Bartlett Reef light vessel, a distance of 4 miles N W by W. The weather is foggy and in making the run by compass, allowance must be made for a current setting E by S and running at a rate of 2½ miles an hour. Find what course should be steered and the time it will take to cover the distance between the two points.

SOLUTION.—Draw the line N S, Fig. 24, to represent the meridian. From the point A on this line draw $A\,B = \text{N } 56° \text{ W} = \text{N W by W}$, the bearing of the lightship from Race Rock light, and make it in length equal to 4 mi. according to an assumed scale. From A draw $A\,C$ to represent the direction of the current and mark off on this $1\frac{1}{4}$ mi. or the distance it will set in $\frac{1}{2}$ hr. With $A\,B$ as a diagonal complete the parallelogram by drawing $A\,D$ parallel with $B\,C$ and $B\,D$ parallel with $A\,C$. The side $A\,D$ then represents the course that must be kept to reach B. Measuring the angle $N\,A\,D$ with a protractor the course to steer to counteract the effect of the current is N 62° W, or N W by W $\frac{1}{2}$ W. Using the same scale it is found that $A\,D$ is $5\frac{1}{4}$ mi. long. This shows that with a boat making 8 mi. an hr., the course N W by W $\frac{1}{2}$ W must be kept up until a distance of $5\frac{1}{4}$ mi. has been covered according to the patent log. The time required to make the run from A to B is therefore a trifle over 39 min. Ans.

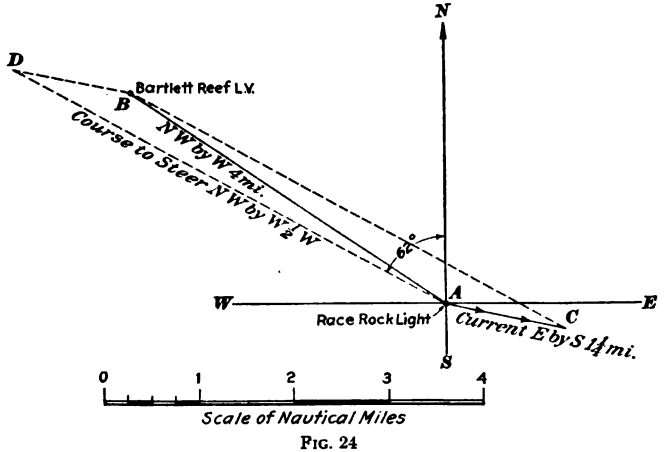

FIG. 24

58. It will be noticed in the solution of Example 2 that the course to steer was obtained by using the speed of the boat and the rate of the current for $\frac{1}{2}$ hour; the same result would be had by using the data for 1 hour as in the preceding example. From a strictly geometrical point of view, a discrepancy may exist in the time estimated and the actual time consumed in making the run for the reason that the current will act on the boat for 39 instead of 30 minutes, the actual time being slightly in excess of the estimated time. For practical purposes, however, the difference may be disregarded.

EXAMPLES FOR PRACTICE

1. Suppose that a port bears east and the set of a current is N N E with a drift of 2 miles an hour, speed of the yacht being 9 knots. What course should be steered to counteract the effect of the current?

Ans. S 78° E

2. A light vessel bears N 75° E and a current is running N 40° W 2 miles an hour, the yacht's speed being 9 knots. Find what course to steer in order to counteract the current and keep the port on the same bearing. Ans. N 86° E

---

59. Finding Set and Rate of a Current.—In most localities there is no way of determining, with certainty, the set and rate of a current likely to be encountered during a run; in such cases, the proper course to be steered must be contingent on actual observations made by the navigator himself. In a fog, the direction of the current may be found by dropping the lead and paying out considerable line. The direction in which the boat is drifting away from the lead as shown by the line is the set of the current. When at anchor, the set and rate of a current is found by the common log; the set, by the direction of the log line; and the rate, by the number of knots run out. A small patent log may be used also for this purpose if the rate of the current is strong, that is, 3 or 4 miles per hour or more.

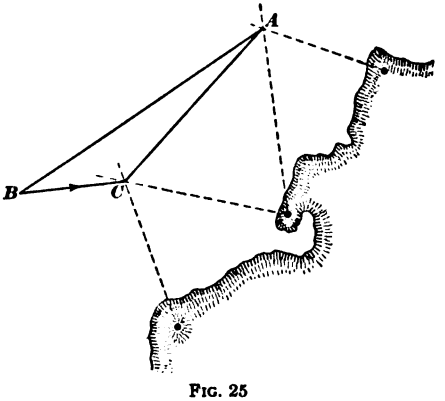

FIG. 25

When running along, in sight of land, the set and drift of a current can be determined as follows: Let *A*, Fig. 25, represent the position of a vessel determined by cross-bearings, or other method, and *A B* the course steered and distance run from that point to another point *B*. At this latter point the vessel's position is again determined by reference to some known object or objects on shore; should this indicate the vessel to be at *C*, it is evident that if *B* and *C* are connected by

a straight line, the magnitude and direction of *B C* will represent the set and rate of the current that the vessel experienced during her run from *A* to *B*.

60. Charts generally show the direction or set of a current by means of an arrow, and its mean or average hourly rate is usually indicated by a numeral close by. But, it must be borne in mind that the direction of the arrow does not always correspond with the actual set of the current as the latter may vary from several causes. The rate, also, of a current constantly varies with circumstances, and the rate given on the chart is merely the mean of those found during the survey, possibly from very few observations.

61. The Currents.—Tidal currents may be allowed for beforehand because they are closely connected with high and low water. Many persons are under the impression that high and low water mean slack water; that a falling tide means a current running out, and a rising tide a current running in. However, this is far from being true, for in many places the tidal current runs at its greatest rate at the time of high and low water. It is along an open coast line only and in an open shallow bay where slack water corresponds with high and low water of the tide. A case in point is the Chesapeake Bay, where the wave of high water travels up until it reaches and is reflected back from the head of the bay. This produces a rather peculiar condition of two points of high and two points of low water with an era of slack water midway between the adjoining high and low tides. For this reason special caution is necessary in navigating waters where the formation of the coast and the contours of the bottom are such as to cause irregularities in the currents produced by the tides. It should be remembered that there are indrafts to all bays and bights, though the general direction of the current may be parallel with the shore.

62. In one of its publications the Hydrographic Office illustrates the effect of the tidal wave in causing currents by the two following cases: (1) Where there is a small tidal

basin connected with the sea by a large opening; (2) where there is a large tidal basin connected with the sea by a small opening.

In the first case the velocity of the current in the opening will have its maximum value when the height of the tide within is changing most rapidly; that is, at a time about midway between high and low water. The water in the basin keeps at approximately the same level as the water outside. The flood stream corresponds with the rising and the ebb with the falling of the tide.

In the second case, the velocity of the current in the opening will have its maximum value when it is high water or low water without, for then there is the greatest head of water for producing motion. The flood stream begins about 3 hours after low water, and the ebb stream about 3 hours after high water, slack water thus occurring about midway between the tides.

Along most shores not much affected by bays, tidal rivers, etc., the current usually turns soon after high water and low water.

The swiftest current in straight portions of tidal rivers is usually in the middle of the stream, but in curved portions the most rapid current is toward the outer edge of the curve, and here the water will be deepest. The pilot rule for best water is to follow the ebb-tide reaches.

Countercurrents and eddies may occur near the shores of the straits, especially in bights and near points. A knowledge of them is useful in order that they may be taken advantage of or avoided.

A swift current often occurs in the narrow passage connecting two large bodies of water, owing to their considerable difference of level at the same instant. The several passages between Vineyard Sound and Buzzards Bay are cases in point. In the Woods Hole passage, the maximum strength of the tidal streams occur near high and low water.

Tide rips are made by a rapid current setting over an irregular bottom, as at the edges of banks where the change of depth is considerable.

63. For power boats navigating in waters along and adjoining the coast line, a knowledge of tides and their attendant currents is of first importance. Not only should the Tide Tables and the Coast Pilot be carefully studied for the locality in which a run is expected to be made, but all available local knowledge pertaining to currents should be gathered and made use of. The United States Coast Pilot in particular should be studied as it contains practically all information needed for the navigation of any river, bay, harbor, or inlet along the coast.

SUGGESTIONS TO MOTOR-BOAT OPERATORS

64. The following notes relating to the appearance and colors of waters, and the handling of boats under various conditions of the sea, will be of interest to operators of medium-sized motor boats, particularly those that for some reason do not carry a compass. The suggestions given are general and if carried out in combination with a judicious use of the lead or sounding pole may prove helpful to operators having little or no previous experience.

65. Indications of Shallow Water.—On approaching a shoal spot in the water the attention of an observer will be attracted by either a rise in the height of the waves, causing them to curve over and break, or by their taking on a troubled, agitated appearance, in marked contrast to the waves in the deeper water. The extent of the irregular water, will, in most cases, clearly define the limits of the shoal. When traversing shoal places, the deepest water will always be found where the waves are of normal size and most regular in appearance; they will be clearly distinguished from either of the lifting kind, which is inclined to topple and break, or the smaller jumbled type. At times, the water over the shoal will be smooth and the water in the channels ruffled; this is particularly liable to be the case when the shoal bordering the channel has a growth of weeds reaching nearly to the surface.

66. If in strange waters and a line of ripples stretches across the course, the ripples should be approached with caution.

The line may be a tide ripple marking the changing of the tide or it may be a reef or bar fairly close below the surface. These small ripples are often seen along the edge of shoals when the surrounding water is smooth, particularly when the outside water is deep; they are caused by the flow of the tide being shunted off by the shoal. When traversing a shoal during a strong breeze, having from 3 to 20 feet depth of water over it, the deeper parts may invariably be distinguished by watching for the heavier, more regular waves, while the shallow spots of the shoal are indicated by choppy, breaking waves.

67. Crossing a Bar.—Necessity may at times compel the passage of a boat through a reef, or a bar, over which a strong sea is running. In such cases it is well to run slowly along the reef at a moderate distance and search carefully for regular waves. If there is an opening, or channel, through, it will show water distinctly different from that over the rest. In such deep places, the water will remain without breaking until the sea has attained such violence that even the deep places have practically become shoals. The passage through comparatively unknown reefs and bars when heavy weather prevails should not be attempted except by the most experienced men. The sea may look smooth and regular at some distance off the bar but on approaching, the conditions may be such as to require an intuitive skill at the helm to get the boat safely through.

Another useful thing to remember in connection with waves is to watch the progress of a large steamer going up a harbor or river and it will be but a short time when the action of its swell will reveal by the manner of breaking, every shoal spot in the vicinity.

68. Wave Motion.—To run smoothly, a wave requires a depth of water as great as is the distance from its own trough to trough. If that distance is 15 feet, the wave requires 15 feet of water to roll in or it will begin to rise in height and form a crest, this being the result of the friction of the wave motion on the bottom. It is the wave motion that travels, not the water, as can be readily seen by dropping a colored liquid of

any kind into the sea; the colored liquid will remain practically stationary, or nearly so, while the motion of the wave will continue to advance.

When running along a beach at night, the beach being free from rocks, the line of safety can be felt by the lifting of the boat; if too close in, a sharp lift will be felt when a sea passes under, the lift being distinctly different to that felt when the boat was in deep water, and is a sure indication that the boat is within the line where the wave begins to top the breaker. In a heavy on-shore wind, the best traveling will be found a mile or more off-shore. The reason is that heavy seas striking a beach, or reef, give a strong recoil that cause a series of opposing waves which, meeting those coming in, cause rough, irregular water.

Occasionally there will be seen a solitary lift or leap of the water where there are no other evidences of disturbances; this is generally caused by a small mound or boulder rising at that spot from the bottom.

69. Tide Rips.—Tide rips are the result of strong currents. With no visible signs of disturbance and the sea smooth all about them waves of this character will rear and tumble. They are clearly distinct from anything about them, and do not take one unawares. Almost invariably they have white foaming crests and roar in an unmistakable manner. Even in a white-cap breeze, they are clearly whiter than anything about them. They are so clearly marked that one can sail down their edges and admire the wildness of the scene. The wave motion in them is short and steep. When wind increases their turbulence none but the staunchest of boats and best of helmsmen should attempt to enter the turmoil. At the slack of the tide the tide rips do not exist. When compelled to encounter them in bad weather the boat should be kept to the edges where the water is always deep. If in the rip and it is running strong, which is generally the case during 4 hours out of the six, the boat should be kept head-to; she will lift and pound badly and perhaps get strained, but that is better than the risk of rolling over.

70. Head Sea.—During a hard blow, the sea will be found to present waves that are regular in general but interspersed with seas that are too sharp for comfort for a boat of light construction. If going to windward, many of these seas will compel one to head into them; then will come a lift and, if the boat has not a sharp **V** section forward, a smashing fall down the back of the wave. These falls pound the bottom of a boat so severely that it is not good practice to permit many of them. They are avoided by turning the boat a trifle off from directly into the wave, though if the wave is steep enough to throw the boat there is no help but to take it head on. Should swinging her off to give more bearing surface take the boat too much off the course the remedy is to take the seas on one bow for a stated time and then on the other bow for the same length of time; the result being the equalizing of the course.

71. Following Sea—Running with a following sea gives the helmsman the hardest task he can have. When a sea passes under the boat, lifting the bow the next wave comes under the stern and begins to lift; when the stern has been raised to a greater height than the bow the latter begins to *root;* which means that the boat is "down by the head," and does not respond to the rudder. This is the anxious moment for the helmsman as he waits for the feeling that comes with a submerged rudder indicating the direction in which the bow is going to turn. So long as the rudder is out of water it should be kept steady by the wheel and the instant the feeling comes that it is submerged the wheel should be turned, gently at first, then with all the strength necessary to counteract the sheer; then the wheel should be allowed to turn back freely as the boat balances on the forward drive on the face of the wave.

During this maneuvering the bow of the boat may root until 2 or 3 feet of it is buried in the sea ahead. It will not do to let this take place for, as explained previously, the water is not moving and the boat is plowing into it and while doing so the stern may be lifted so high that the boat has no bearing, in which event she will either dive or roll over. This is what

takes place with boats trying to enter a surf or a harbor having a bar before the entrance, while the weather is heavy from seawards. The remedy is the same in either case, and is the one commonly employed by life savers in making a landing; that is, to tow a drag or sea anchor. If without one any bulky article attached to a stout line may be dropped over the stern and towed. The resistance offered will help materially in checking the tendency to root.

72. With some boats and some seas it will be found that the bow is rooting and the stern is being boarded by the following seas. This is a bad case. All the available weight (passengers, etc.) must then be placed amidship to lighten the ends and the boat swung a very little from a fore-and-aft bearing on the seas. If the boat is of the open-cockpit type, canvas should be fastened over the after end of the cockpit. This is a case in which oil might help some by running the boat slowly and putting out the oil from any part of the boat that will cause the slick to be spread by the time it reached the stern. The burying of the bow and stern of a boat with fine sharp ends is of little consequence, as the lack of bearing surface in such boats makes this a condition to be expected, but the sea has not hold enough on either end to do harm, and the end will rise as quickly as the wave passes by.

73. Beam Sea.—In a beam sea, conditions are such as to require the utmost attention on the part of the helmsman. The boat is traveling in the trough and if an on-coming sea is a bad one the judgment must be instantly formed whether to run or head into the sea. The present position of the boat generally governs the maneuver. If the boat has just recovered from a lurch and the bow is too far to windward to give her time to run off she must of necessity be thrown head in. If she is too far off the wind to give her time to be swung up she must be sent to leeward. Most of the time the shape of the seas are such that the boat can be held to the course; this gives the helmsman the choice of the maneuver.

74. Lee Shore.—When running along a lee shore for any considerable distance the scend of the sea will steadily set the

boat toward the beach. There is seldom such a sea but that smooth well-rounded waves are mingled with the rough ones; with every smooth sea the boat should be sent on the course as far as she will go and sent to windward in the rough ones, and in some of the smooth ones if necessary, but in no case to leeward.

During a blow a boat should pass to the lee side of islands where it is possible to do so; also, to the lee side of shoals; no shoal is so deep but that it has an influence in smoothing the sea. A shoal near the surface will stop the sea altogether and leave only the wind for the boat to contend with.

75. Fog.—If caught in a fog without a compass, the best way in which to prevent a boat from losing her direction is to make use of the run of the waves. If the waves were coming toward the starboard bow when the fog set in, they should be kept coming from the same quarter.

To trail a line over the stern will keep one running, straight ahead, and not in a circle as is often done. The longer the line the better; any swerving from a straight course will then show at once.

To verify the steering in a fog or rain the fall of rain drops or of any drizzle may be made use of by watching its slant.

In many sections the ripples that are always to be found along the side of a reef over which the tide has run are advantageously used as a guide in times of thick weather.

76. Direction of Swell as a Guidance.—If heading for an island, it will be useful to know that waves or swell have a tendency to follow the trend of the land, and if coming around a point will try to curve in and reach the shore parallel to it, instead of running at right angles with it. In a fog this is made use of by boatmen to learn when the shore is being approached as the following illustration goes to show. Suppose the boat *a*, Fig. 26, to be running southeast, the swell coming from the south, and the island *c* for which the boat is bound lies across and very close to the course. In time the swell that has been striking the boat on the starboard bow is observed to be coming more from the side instead of the bow; this tells the

helmsman that the boat has run so far that the end of the island has come between the boat and the swell and that the swell is trying to swing around the corner. Soon the swell is lost altogether, indicating that the island is close by and that the swell cannot curve in far enough to reach it; the position of the boat is then at *b*.

Another way in which swell, or waves, may prove useful to a boat without a compass is when the boat is running for enclosed waters in misty weather. The time in which the boat should have been in touch with her destination may have passed, yet there is no sign of land. Soundings give 6 fathoms

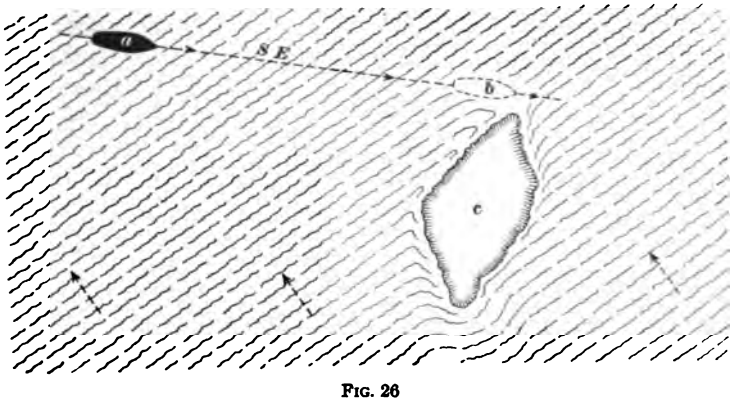

FIG. 26

with sand bottom, which means little, as all of the water within miles of the place is near to that depth. The swell is on the port beam and knowing he is close to the island that the swell is parallel to the shore; therefore, the operator proceeds cautiously, changing his course to follow the trend of the swell. As soon as a perceptible change in the direction of the swell occurs he will know it is caused by the curving of shore line at the entrance of the harbor he is looking for, as shown in Fig. 27, and this will enable him to reach his destination.

77. Reflections of Rocks and Sand.—The majority of rocks and shoals within the range of the cruising power boat are usually unmarked by buoys of any kind, but most of such

obstructions do reflect their colors to the surface of the waters immediately surrounding them. The shade, or density, of the color will vary, with the different phases of the day, from clear distinctness to an indefinable something, yet to the practiced eye they may be distinguished and used with advantage. To cultivate the faculty of observing the different shades of the water well repays the operator of a power boat. It gives a confidence in running that adds to the comfort and interest, and in combination with a judicious use of the lead line, enables him to pick his way into harbors and inlets that are new to him with a degree of certainty. This applies more particularly to fairly clear waters and not such as are found in or close to the harbors of large cities. A mud bottom is not so good as a sand, or rock bottom, but even over a mud bottom there will be a different shade of color between the shallow water and the channels.

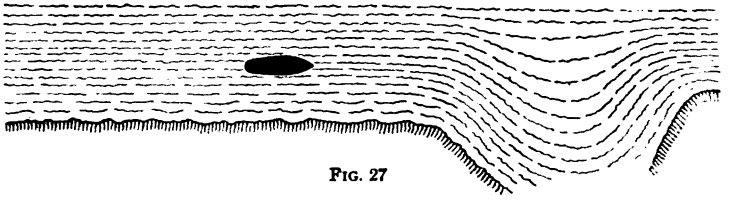

FIG. 27

78. When running in open waters, a faint line may appear at some distance ahead and commence to loom. On a near approach the entrance to a small harbor or inlet may be looked for, though the coast may appear to be one unbroken line. As the boat draws nearer dark spots of brown may be seen at some places, while at others grayish or white shadows prevail; the former indicates deep and the latter shallow water. When approaching to 400 or 500 feet perhaps, close observation will be apt to show water of a decided green tint and water having a certain placid or slick whitish appearance; the latter color should be avoided and the deeper green followed. Then with a good lookout in the bow it will be perfectly safe to proceed slowly into the place as far as is desired; the higher up the man watching the color is placed the better he will see the bottom and select the route to be taken.

79. The entrance to an all-sand harbor over a bar may be made by observing the difference in color when arriving at the 18-foot depth, for the break is clearly visible. When passing into the 12-foot depth, it will be well to slow down to half speed. Here the darker green veins of water should be chosen. They will be seen spreading or rather narrowing from all sides to two or three dark-green streaks. It might be more easily understood by saying that large light-green patches will be seen ahead, which vary in shade from light-green to almost a white, and that between these patches will be seen darker green leads in the water. The darker green leads may run through the center, or away off to one side, but wherever they are they should be followed as they indicate channels. Generally they lead to one main channel that runs into the deeper body of water to be found within.

MOTOR-BOAT RULES AND SIGNALS

FLAG SIGNALS

CODES USED

INTERNATIONAL CODE

1. The **international code of signals,** shown in Fig. 1, consists of twenty-six flags, namely, two burgees, five pennants, and nineteen square flags besides the code flag, which is used also as the *answering pennant.* The object of this code is to supply a means of communication between ships meeting at sea and between ships and established signal stations on shore. The code, therefore, has been adopted by all the leading maritime powers of the world, and the interpretations of the several thousand distinct signals composing the system have been translated into the language of each of these nations. Ships of different nationalities when meeting at sea are consequently enabled to communicate with each other, even though neither commander is able to use the language of the other in conversation.

2. Every seagoing vessel carries a set of these flags as well as a code book, in which are given upwards of 75,000 distinct and separate signals made up in hoists of from two to four flags. These signals cover every conceivable message that may be required in any part of the world and under all sorts of conditions in which a vessel may find herself.

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YACHT-CLUB SIGNAL CODE

3. For the purpose of communication between yachts and other pleasure craft that do not need so elaborate a signal system as that composing the international code, a simplified code of signals has been prepared. This code, which was first adopted by the New York Yacht Club, is now in general use by yachtsman and motor-boat operators all over the United States. Its simplicity consists in the use of but one or two flags in one hoist for signaling sentences that by the international code would require three and four flags to make up the hoist.

4. The signals in the yacht-club code consist chiefly of the sentences most used when communicating between yachts. They are arranged in groups as follows: Special signals, general signals, days of the week, hours of the day, and names of places.

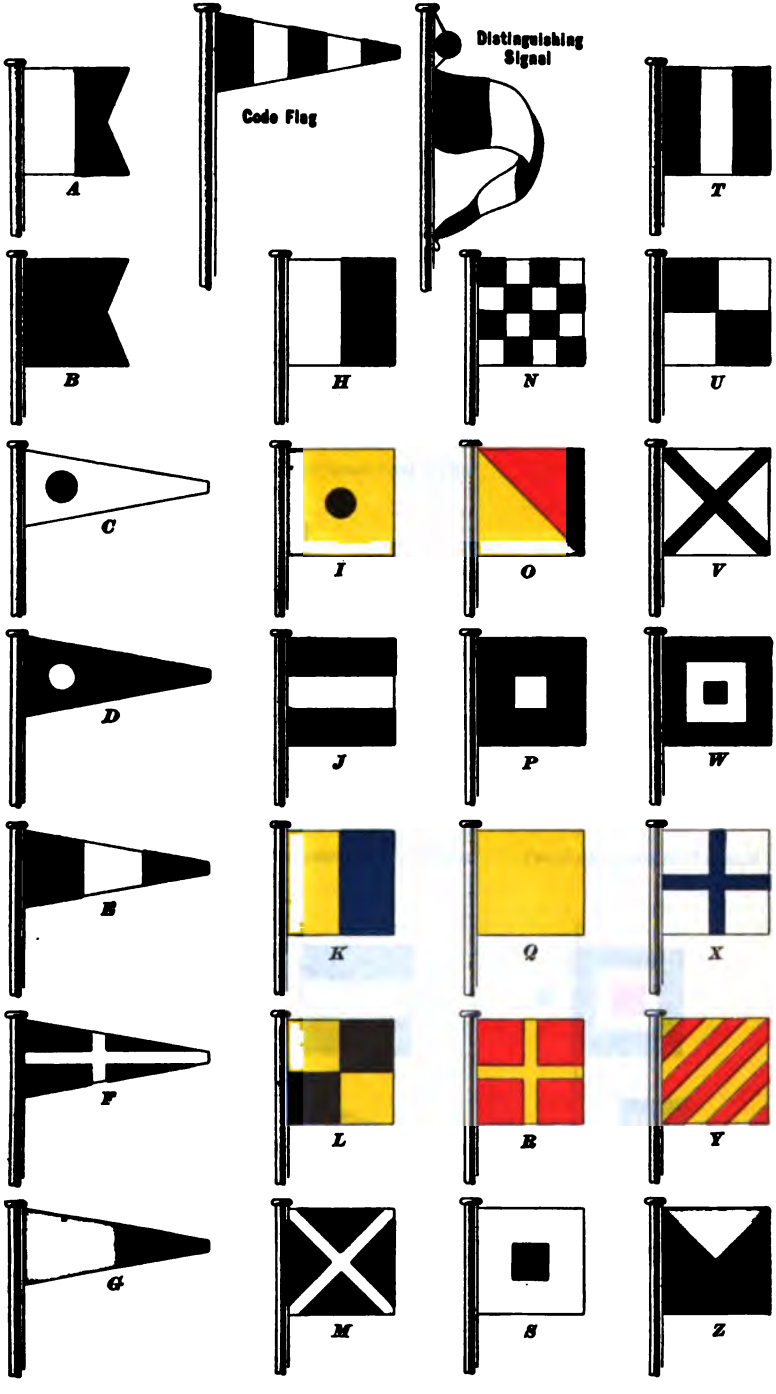
The *special signals* are made up of a single flag or pennant and run from *A* to *Z*; the *general signals* are two-flag signals running from *B A* to *G Z*. *Signals pertaining to days of the week* are two-flag signals and run from *I Q* to *I Z*. *Signals relating to hours of the day* run from *J A* to *K Z*. *Signals relating to localities* and geographical places are also two-flag signals and run from *N A* to *W I*. *Compass signals* are the only signals in which three flags are used in one hoist, the same as in the international code; they run from *A Q D* to *A S T*.

5. Rules for Signaling.—When intending to use the international code in place of the club code, it is necessary to display the regular signal indicative of the international code; namely, the United States ensign hoisted over the answering pennant, as shown in Fig. 2. In the absence of this signal, it will be understood that the yacht-club signal code is being used.

When signaling a particular yacht, its International number, consisting of four letters, which is assigned by the Bureau of Navigation, Department of Commerce, should be hoisted and it alone should answer.

When signaling a club station, the burgee should be hoisted over the signal.

CODE FLAGS AND PENNANTS
INTERNATIONAL CODE OF SIGNALS



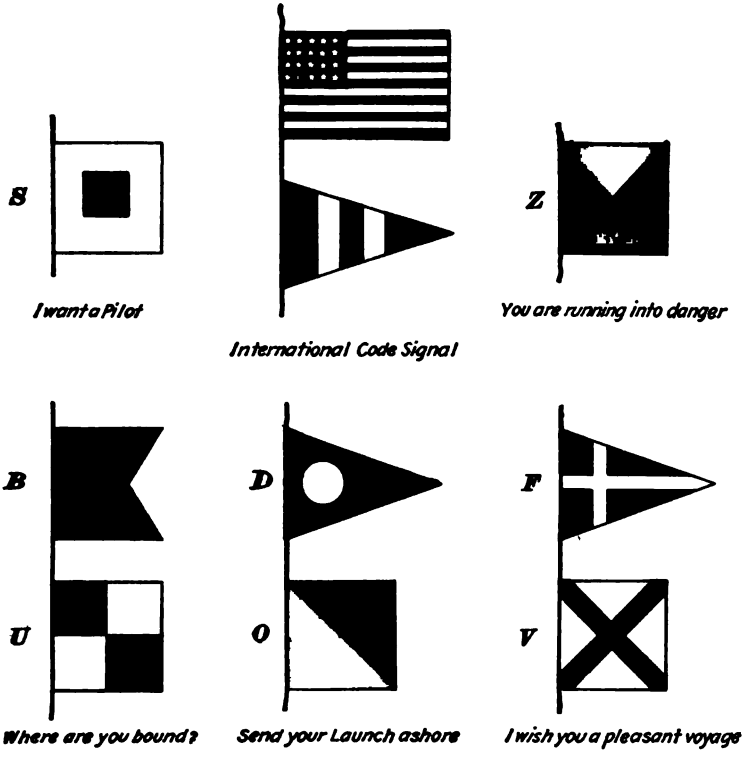

S
I want a Pilot
International Code Signal
Z
You are running into danger
B
U
Where are you bound?
D
O
Send your Launch ashore
F
V
I wish you a pleasant voyage
N
H
Bar Harbor, Me.
J
D
1:30 P.M.
W
A
Port Huron, Mich.

FIG. 2

Signals should be acknowledged as soon as understood, by hoisting the answering pennant where it can best be seen. It should be kept flying until the signals are hauled down, and then be promptly lowered.

The square flag *P* hoisted simultaneously, but on another hoist, with any other signal will indicate that the signal is a preparatory one

6. Remarks on Signaling.—In connection with the make-up and interpretation of signals, it is important to learn, first of all, to distinguish the flags so as to be able to tell at a glance what letters are contained in a hoist. This will greatly facilitate signaling and do away with the necessity of having to refer at all times to the colored plate to read a signal displayed by another vessel. In the yacht-club code, every flag, pennant, or burgee displayed single has a special meaning. Many of them refer to orders and phrases used during a race and are for this reason as applicable to motor boats as they are to sailing yachts. Others signify urgent messages, such as *A*, which means accident; *R*, man overboard; *Q*, that a surgeon is wanted; and *Z*, which is a warning of danger. The letter *B* displayed alone is a signal of protest; in some instances, it is used also on a race-committee boat to indicate an order that the course to be run is in a direction opposite to that originally ordered. In Fig. 2, are shown the principal forms of hoists used in the yacht-club code, the interpretation of the respective signals being printed under each. Compass signals alone are made up of three flags in one hoist and are seldom used except in races between sailing yachts.

7. When signaling flags should be hoisted where they can best be seen by the vessel for which the signal is intended; also each hoist should be kept flying until the other vessel has signified that the signal is understood. Care should be taken not to hoist a two- or three-flag signal in an up-and-down position or with the uppermost flag down, which sometimes occurs when signals are sent up in a hurry. When making up a hoist of two- or three-flag signals, it is necessary to remember that the flag representing the letter first printed in the list should be at the top of the hoist.

YACHT-CLUB SIGNAL CODE

SPECIAL SIGNALS

SIGNALS	MEANING
A	Accident
B	Protest
C	Yes, affirmative, assent
D	No, negative, refusal
E	Do you assent to postponing the race until later in the day?
F	Do you assent to calling race off for the day?
G	Race postponed until later in the day
H	Race postponed for the day
I	Race postponed
J	Race is off
K	Race will be called at
L	Finish race off
M	Race will finish at end of first round
N	The starting line will be shifted
O	Mark has shifted; this vessel is the mark
P	Preparatory signal
Q	Surgeon is wanted on board immediately
R	Man overboard
S	I want a pilot
T	Club launch wanted
U	Get under way at
V	Permission to leave squadron is requested
W	Permission to disregard orders is requested
X	Permission granted
Y	Come within hail
Z	You are running into danger

GENERAL SIGNALS

SIGNALS	MEANING
B A	Start at
B C	Start from
B D	Start for
B E	The fleet will not start at present
B F	The fleet will not start today
B G	The fleet will not start until
B H	Proceed to
B I	Proceed at will
B J	May I proceed at will?
B K	Proceed to at
B L	Anchor near me
B M	Anchor at
B N	Where are we to anchor?
B O	Anchor for the night at
B P	Anchor at will
B Q	Return to anchorage
B R	Are you going to anchor at?
B S	Anchor clear of the channel
B T	Intend to anchor during fog
B U	Where are you bound?
B V	Bound for
B W	Where are you from?
B X	Come from
B Y	When did you leave (or pass)?
B Z	
C A	Regatta committee report on board this vessel at
C B	Is regatta committee on board?
C D	When will race be started?

SIGNALS	MEANING
C E	Race will be started at
C F	Do you agree to race tomorrow?
C G	The course will be
C H	Course No. 1
C I	Course No. 2
C J	Course No. 3
C K	Course No. 4
C L	Course No. 5
C M	Report of regatta committee now ready
C N	Spare hands for race wanted
C O	Will you join squadron at?
C P	Will join squadron at
C Q	Take time at finish
C R	This yacht will take time at finish
C S	Finish here
C T	Single-masted vessels and yawls
C U	Schooners
C V	Sloops
C W	Yawls
C X	Steam yachts
C Y	Auxiliaries
C Z	Power boats
D A	Do you understand my signal?
D B	Cannot understand your signal
D C	Repeat my signal
D E	Have you an international code book?
D F	Have no international code book
D G	Shift signal to more conspicuous hoist
D H	Signal not understood though flags are distinguished
D I	Previous signal is annulled
D J	Unable to comply with signal
D K	Dress ship tomorrow at morning colors
D L	The fleet will illuminate at
D M	Dress ship at
D N	Send your boat ashore
D O	Send your launch ashore
D P	Send your boat alongside
D Q	All boats belonging to this yacht return at once
D R	Cannot send boat—launch—dingey
D S	Pick up, boat's adrift
D T	
D U	
D V	
D W	
D X	
D Y	
D Z	
E A	Are you in need of assistance?
E B	Am in need of assistance
E C	Vessel is on fire, needs assistance
E D	Am aground
E F	Am afloat
E G	Am dragging
E H	You will be aground at low water
E I	Send towboat
E J	Send hawser
E K	Send anchor
E L	Have you a chart of?
E M	I want a tow
E N	Do you want a tow?
E O	How is the weather outside?
E P	Moderate weather outside
E Q	Heavy weather outside
E R	Fog outside
E S	Clear outside
E T	Calm outside
E U	There is a sea on
E V	Wind outside is from
E W	Where can I get coal?
E X	Where can I get water?
E Y	Need a surgeon; send one from nearest place
E Z	Is there a surgeon (or doctor) in the squadron?

Signals	Meaning
F A	Captains report on board flagship at
F B	Captains and guests are invited on board flagship at
F C	Captains report on board flagship on coming to anchor
F D	Meeting of captains postponed until
F E	Report on board at
F G	All yachts in squadron send a boat to flagship for instructions
F H	
F I	Commodore
F J	Vice-commodore
F K	Rear commodore
F L	Junior flag officers
F M	Secretary
F N	Fleet captain
F O	Fleet surgeon
F P	Measurer
F Q	Regatta committee
F R	Club station
F S	Send a boat to flagship
F T	Wish to communicate with you
F U	Congratulations. Well done
F V	I wish you a pleasant voyage
F W	Thank you
F X	(*Name*) will be the committee boat
F Y	Divine service will be held on board flagship at
F Z	Squadron is disbanded
G A	Will you come on board at?
G B	Will you breakfast with me at?
G C	Will you lunch with me at?
G D	Will you dine with me at?
G E	Will meet you on shore at
G F	Will meet you at the club at
G H	Will be on board at
G I	And bring your guests
G J	Send a boat for me
G K	Am not going ashore
G L	When do you go ashore?
G M	Previous engagement prevents
G N	
G O	Order a carriage for me
G P	Order a coupé for me
G Q	Order an automobile for me
G R	Will send a reply
G S	Are there any letters for me at?
G T	Mail for you ashore at
G U	Bring or send my mail
G V	Can you take a letter or telegram for me?
G W	At once
G X	Have you any newspapers?
G Y	
G Z	

DAYS OF THE WEEK

Signals	Meaning
I Q	Sunday
I R	Monday
I S	Tuesday
I T	Wednesday
I U	Thursday
I V	Friday
I W	Saturday
I X	Today
I Y	Tomorrow
I Z	Yesterday

HOURS OF THE DAY

SIGNALS	MEANING	SIGNALS	MEANING
J A	12 noon.	*K A*	12 midnight.
J B	12.30 P. M.	*K B*	12.30 A. M.
J C	1.00 P. M.	*K C*	1.00 A. M.
J D	1.30 P. M.	*K D*	1.30 A. M.
J E	2.00 P. M.	*K E*	2.00 A. M.
J F	2.30 P. M.	*K F*	2.30 A. M.
J G	3.00 P. M.	*K G*	3.00 A. M.
J H	3.30 P. M.	*K H*	3.30 A. M.
J I	4.00 P. M.	*K I*	4.00 A. M.
J K	4.30 P. M.	*K J*	4.30 A. M.
J L	5.00 P. M.	*K L*	5.00 A. M.
J M	5.30 P. M.	*K M*	5.30 A. M.
J N	6.00 P. M.	*K N*	6.00 A. M.
J O	6.30 P. M.	*K O*	6.30 A. M.
J P	7.00 P. M.	*K P*	7.00 A. M.
J Q	7.30 P. M.	*K Q*	7.30 A. M.
J R	8.00 P. M.	*K R*	8.00 A. M.
J S	8.30 P. M.	*K S*	8.30 A. M.
J T	9.00 P. M.	*K T*	9.00 A. M.
J U	9.30 P. M.	*K U*	9.30 A. M.
J V	10.00 P. M.	*K V*	10.00 A. M.
J W	10.30 P. M.	*K W*	10.30 A. M.
J X	11.00 P. M.	*K X*	11.00 A. M.
J Y	11.30 P. M.	*K Y*	11.30 A. M.

NAMES OF PLACES

SIGNALS	MEANING	SIGNALS	MEANING
N A	Absecon lights, N. J.	*N O*	Bay Ridge, N. Y. Bay
N B	Annapolis, Md.	*N P*	Beaver Tail, R. I.
N C	Ardsley on Hudson, N. Y.	*N Q*	Belfast, Me.
N D	Atlantic Highlands, N. J.	*N R*	Beverly, Mass.
N E	Bakers Island light, Me.	*N S*	Black Rock harbor, Conn.
N F	Baltimore, Md.	*N T*	Block Island, R. I., East Harbor
N G	Bangor, Me.	*N U*	Block Island, West Harbor, Great Pond
N H	Bar Harbor, Me.	*N V*	Brenton Reef light vessel
N I	Bar Island, north side of Bar Harbor, Me.	*N W*	Bristol, R. I.
N J	Barnegat light, N. J.	*N X*	Boon Island, Me.
N K	Bartlett Reef light vessel	*N Y*	Boothbay, Me.
N L	Bath, Me.	*N Z*	Boston, Mass.
N M	Bass Harbor, Me.		

Signals	Meaning
O A	Boston light vessel, Mass.
O B	Camden, Me.
O C	Campobello, N. B.
O D	Cape Ann, Mass.
O E	Cape Charles, Va.
O F	Cape Cod, Mass.
O G	Cape Elizabeth, Me.
O H	Cape Hatteras, N. C.
O I	Cape Henlopen, Del.
O J	Cape Henry, Va.
O K	Cape May, N. J.
O L	Cape Poge, Mass.
O M	Cape Porpoise Harbor, Me.
O N	Cape Sable, N. S.
O P	Captains Island lighthouse, Conn.
O Q	Casco Bay, Me.
O R	Casco Passage, Me.
O S	Castine, Me.
O T	Chatham lights, Mass.
O U	Chatham Roads, Mass.
O V	City Island, N. Y.
O W	Cold Spring Harbor, Long Island, N. Y.
O X	Clarks Point, Buzzards Bay, Mass.
O Y	Coney Island Point, N. Y.
O Z	Cornfield Point light vessel
P A	Cranberry Island, Me.
P B	Cross Rip light vessel
P C	Cutler, Little River, Me.
P D	Cutty Hunk, Mass.
P E	Deer Island Thorofare, Me.
P F	Delaware Breakwater, Del.
P G	Duck Island breakwater,
P H	Dutch Island Harbor, R. I.
P I	East Chop, Vineyard Haven, Mass.
P J	Eastern Point breakwater, Mass.
P K	Eastport, Me.
P L	Eaton's Neck, N. Y.
P M	Edgartown, Mass.
P N	Eggemoggin Reach, Me.
P O	Egg Rock, Frenchman's Bay, Me.
P Q	Falkner Island, Conn.
P R	Fire Island, N. Y.
P S	Fire Island light vessel
P T	Fisher's Island Sound
P U	Five Fathom Bank light vessel
P V	Franklin Island lighthouse, Me.
P W	Fort Pond Bay, N. Y.
P X	Fortress Monroe, Va.
P Y	Fox Island Thorofare, Me.
P Z	Gardners Island, N. Y.
Q A	Gardners Bay, N. Y.
Q B	Gay Head, Mass.
Q C	Gilkey Harbor, Isleboro, Me.
Q D	Glen Cove, N. Y.
Q E	Gloucester, Mass.
Q F	Gloucester, Eastern Point
Q G	Goat Island, Me.
Q H	Grand Manan, N. B.
Q I	Grand Manan Channel, N.B.
Q J	Graves, The, Mass.
Q K	Gravesend Bay, N. Y.
Q L	Greenport, N. Y.
Q M	Greenwich, Conn.
Q N	Greeves Ledge light, Norwalk, Conn.
Q O	Half Way Rock, Mass.
Q P	Half Way Rock, Me.
Q R	Halifax, N. S.
Q S	Hampton Roads, Va.
Q T	Hardings Ledge, Mass.
Q U	Harpswell Sound, Me.
Q V	Head Harbor, N. B.
Q W	Hen and Chickens light vessel, Mass.
Q X	Highland light, Mass.
Q Y	Horseshoe, N. J.
Q Z	Horton Point, N. Y.
R A	Hull, Mass.
R B	Huntington Bay, N. Y.
R C	Hyannis Port, Mass.
R D	Isles of Shoals, N. H.

SIGNALS	MEANING
R E	Kittery, Me.
R F	Larchmont Harbor, N. Y.
R G	Lloyd Harbor, N. Y.
R H	Machiasport, Me.
R I	Marblehead, Mass.
R J	Marblehead Rock, Mass.
R K	Martinicus Island, Me.
R L	Mattinicock Point, N. Y.
R M	Monhegan, Me.
R N	Monomoy, Mass.
R O	Montauk Point, N. Y.
R P	Morris Cove, Conn.
R Q	Mount Desert Rock, Me.
R S	Muscle Ridge Channel, Me.
R T	Nahant, Mass.
R U	National Harbor of Refuge, Del.
R V	Nantasket Roads, Mass.
R W	Nantucket, Mass.
R X	Nantucket Shoals
R Y	Napeaque, N. Y.
R Z	Narragansett Pier, R. I.
S A	Nauset Beacons, Mass.
S B	New Bedford, Mass.
S C	Newburyport, Mass.
S D	New Haven, Conn.
S E	New London (town), Conn.
S F	New London lighthouse, Conn.
S G	Newport, R. I.
S H	New Rochelle, N. Y.
S I	New York, N. Y.
S J	Norfolk, Va.
S K	North East End light vessel, N. J.
S L	North East Harbor, Me.
S M	Northport, N. Y.
S N	Old Field Point light, N. Y.
S O	Oyster Bay, L. I., N. Y.
S P	Orient Point light, N. Y.
S Q	Peaks Island, Portland, Me.
S R	Penfield Reef light, Conn.
S T	Plum Gut, N. Y.
S U	Point Judith, R. I.
S V	Point Judith Breakwater, R. I.
S W	Pollock Rip light vessel, Mass.
S X	Port Jefferson, N. Y.
S Y	Portland, Me.
S Z	Portland light vessel
T A	Portsmouth, N. H.
T B	Portsmouth, Little Harbor, N. H.
T C	Potts Harbor, Me.
T D	Provincetown, Mass.
T E	Providence, R. I.
T F	Quick's Hole, Mass.
T G	Race Rock light, N. Y.
T H	Race, The, N. Y.
T I	Riverside, Conn.
T J	Rockland, Me.
T K	Rockport, Me.
T L	Sag Harbor, N. Y.
T M	Salem, Mass.
T N	Sandy Hook, N. J.
T O	Sandy Hook light vessel
T P	Saybrook breakwater, Conn.
T Q	Sea Grit light, N. J.
T R	Seal Island light, N. S.
T S	Seguin Island, Me.
T U	Scotland light vessel
T V	Sheffield Island lighthouse, Conn.
T W	Shelter Island, N. Y.
T X	Shinnecock light, N. Y.
T Y	Shrewsbury Rocks, N. J.
T Z	Small Point Harbor, Me.
U A	Somes Sound, Me.
U B	South West Harbor, Me.
U C	South West Ledge, New Haven, Conn.
U D	St. John, N. B.
U E	Stamford, Conn.
U F	Stapleton, Staten Island, N. Y.
U G	Stonington, Conn.
U H	Stratford Point light, Conn.

SIGNALS	MEANING
U I	Stratford Shoal light vessel, Conn.
U J	Tarpaulin Cove, Mass.
U K	Tennent Harbor, Me.
U L	Thimble Islands, Conn.
U M	Tompkinsville, Staten Island, N. Y.
U N	Twenty-Third Street, East River, N. Y.
U O	Vineyard Haven, Mass.
U P	Vineyard Sound light vessel, Mass.
U Q	Watchhill, R. I.
U R	West Chop, Mass.
U S	West Island, R. I.
U T	Whitehead Island light, Me.
U V	Whitestone Landing, N. Y.
U W	Winter Harbor, Me.
U X	Woods Hole, Mass.
U Y	Wood Island, Me.
U Z	Port Clyde, Me.

PORTS ON THE GREAT LAKES

SIGNALS	MEANING
V A	Alexandria Bay
V B	Alpena
V C	Buffalo
V D	Charlotte
V E	Chicago
V F	Cleveland
V G	Coburg
V H	Country Club
V I	Detroit
V J	Duluth
V K	Dunkirk
V L	Erie
V M	Georgian Bay
V N	Goodrich
V O	Green Bay
V P	Hamilton
V Q	Harbor Beach
V R	Harbor Point
V S	Houghton
V T	Lake St. Clair
V U	Mackinaw Island
V W	Marquette
V X	Milwaukee
V Y	Nipegon
V Z	Oswego
W A	Port Huron
W B	Presque Isle
W C	Put-in-Bay
W D	Sacketts Harbor
W E	Sandusky
W F	Sault Ste. Marie
W G	Toledo
W H	Toronto
W I	Welland Canal

COMPASS SIGNALS

(From International Code)

SIGNALS	MEANING
A Q D	North
A Q E	N ½ E
A Q F	N by E
A Q G	N by E ½ E
A Q H	N N E
A Q I	N N E ½ E
A Q J	N E by N
A Q K	N E ½ N
A Q L	N E
A Q M	N E ½ E
A Q N	N E by E
A Q O	N E by E ½ E

Signals	Meaning
A Q P	E N E
A Q R	E N E ½ E
A Q S	E by N
A Q T	E ½ N
A Q U	East
A Q V	E ½ S
A Q W	E by S
A Q X	E S E ½ E
A Q Y	E S E
A Q Z	S E by E ½ E
A R B	S E by E
A R C	S E ½ E
A R D	S E
A R E	S E ½ S
A R F	S E by S
A R G	S S E ½ E
A R H	S S E
A R I	S by E ½ E
A R J	S by E
A R K	S ½ E
A R L	South
A R M	S ½ W
A R N	S by W
A R O	S by W ½ W
A R P	S S W
A R Q	S S W ½ W

Signals	Meaning
A R S	S W by S
A R T	S W ½ S
A R U	S W
A R V	S W ½ W
A R W	S W by W
A R X	S W by W ½ W
A R Y	W S W
A R Z	W S W ½ W
A S B	W by S
A S C	W ½ S
A S D	West
A S E	W ½ N
A S F	W by N
A S G	W N W ½ W
A S H	W N W
A S I	N W by W ½ W
A S J	N W by W
A S K	N W ½ W
A S L	N W
A S M	N W ½ N
A S N	N W by N
A S O	N N W ½ W
A S P	N N W
A S Q	N by W ½ W
A S R	N by W
A S T	N ½ W

WIGWAG SIGNALING

HAND-FLAG SIGNALS

8. As a means of quick and handy communication between motor boats when at anchor at some distance from each other and in cases when the wind is such as to make it difficult to distinguish with certainty between a pennant and a square flag, or the wind is not of sufficient force to blow out the flags of the yacht-club code, the wigwag method of signaling may be used with advantage. In the wigwag code each letter of the alphabet and single numeral is represented by a number made up of the numerals *1*, *2*, and *3*. It may be sent by the use of a hand flag, a hat, or any other convenient article visible by day;

or, by a torch, a lantern, a beam of searchlight, or an electric portable at night.

9. Signaling With Hand Flags.—When signaling with the hand flag, the sender should face the boat or person he wishes to communicate with holding the flag vertically in front of the center of his body, as shown in Fig. 3, (*a*), with the butt at the height of his waist. The motion representing the figure *1* is made by waving the flag down to the *right*, as in (*b*), the figure *2* by waving the flag to the *left*, as in (*c*), while the figure *3* is represented by a motion of the flag from the position shown in (*a*) to that shown in (*d*). Each motion should embrace an

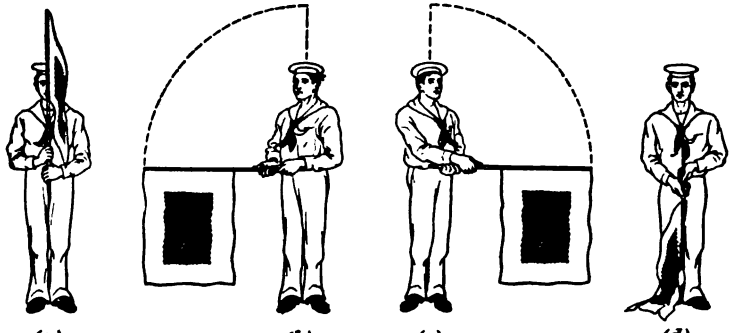


FIG. 3

arc of 90° starting from and returning to the vertical position shown in (*a*). When two or more motions are required to make a letter, there should be no pause between the motions. At the end of each letter, there should be a slight pause at position (*a*); and at the end of each word spelled, one front motion *3* should be made, as in (*d*). At the end of a sentence, two front motions *3 3* should be made; and at the end of a message, three front motions *3 3 3* should be made.

10. Signaling With Lamps.—When an oil lantern or an electric portable lamp is used, the arc of motion is started from the sender's feet 90° to either side for *1* and *2*, while *3* is made by raising the lantern vertically from the feet.

11. Wigwag Code.—The number corresponding to each letter of the alphabet in this wigwag code is as follows:

Letter	Signal	Letter	Signal	Letter	Signal
A —	22	*J* —	1122	*S* —	212
B —	2112	*K* —	2121	*T* —	2
C —	121	*L* —	221	*U* —	112
D —	222	*M* —	1221	*V* —	1222
E —	12	*N* —	11	*W* —	1121
F —	2221	*O* —	21	*X* —	2122
G —	2211	*P* —	1212	*Y* —	111
H —	122	*Q* —	1211	*Z* —	2222
I —	1	*R* —	211		

12. The numerals are represented as follows:

Number	Signal	Number	Signal	Number	Signal
1 —	1111	*5* —	1122	*8* —	2111
2 —	2222	*6* —	2211	*9* —	1221
3 —	1112	*7* —	1222	*0* —	2112
4 —	2221				

13. Conventional signs are made as follows:

Meaning	Signal	Meaning	Signal
End of word	3	Repeat last word	121, 121, 33
End of sentence	33	Repeat last message	121, 121, 121, 333
End of message	333	Move a little to right	211, 211, 3
Error	12, 12, 3	Move a little to left	221, 221, 3
I understand	22, 22, 3	Signal faster	2212, 3
Cease signaling	22, 22, 22, 333		

Repeat after (word). 121, 121, 3, 22, 3 (word)

Words may also be abbreviated as follows:

Meaning	Signal	Meaning	Signal
after	A	the	T
before	B	you	U
can	C	your	U R
have	H	word	W
not	N	with	W I
are	R	yes	Y
signature follows	SIG 3	Numerals follow, or end	XX 3

Thus, instead of spelling out *you are* in this manner,

$$\overline{Y\ O\ U}\quad \overline{A\ R\ E}$$
$$\overline{111\ 21\ 112}\quad \overline{22\ 211\ 12},$$

these words may be sent as follows:

$$\overline{U\ R}$$
$$\overline{112\ 211}.$$

14. Using the Wigwag Code.—To call a yacht by means of the wigwag code, the initial letter of her name should be signaled until answered. To answer a call, the signal *A, A, 3* (22, 22, 3) meaning "I understand" should be made.

If the sender makes an error, he should immediately signal *E, E, 3* (12, 12, 3) "I have made an error" and resume the message beginning with the last word sent correctly.

If the receiver does not understand a signal, he should signal *C, C, 33* (121, 121, 33) meaning "repeat last word"; the sender should then repeat the last word and proceed with the message.

To attract the attention of a yacht with whom it is desired to communicate, at an anchorage for instance, the whistle should be blown or a shot fired from a pistol, then initial letter of the yacht wanted should be signaled.

SEMAPHORE HAND-FLAG SIGNALING

15. In the wigwag code it will be noticed only one flag is used for signaling. In the semaphore hand-flag system, shown in Fig. 4, two flags are used, one in each hand of the sender. By manipulating the flags in the different positions indicated, every letter of the alphabet is represented enabling words to be spelled out in the ordinary way. As in the wigwag system, when signaling another vessel, the sender must face the receiver standing in a place that is plainly in view of the other. To call a yacht, her initial letter, or her full name, if necessary, must be signaled until an answer is received; then the message should be sent, a pause being made at end of each word as indicated in the figure.

Instead of spelling out words, letters in the yacht-club signal code can be used in this system to send messages corresponding to that code. For example, signaling the letters *F T* means "I wish to communicate with you" according to the club code. This greatly simplifies the sending of signals, but an understanding must first be communicated to the other that club-code messages are to be sent with hand flags.

A *1*		G *7*		M		S		Y	
B *2*		H *8*		N		T		Z	
C *3* *Repeat*		I *9*		O		U		*Error or Attention End of Sentence*	
D *4*		J		P *Affirmative*		V		*Numeral*	
E *5*		K *0* *Negative*		Q *Interrogatory*		W		*Annulling*	
F *6*		L		R		X		*End of Word*	

FIG. 4

USING SIGNAL FLAGS FOR DRESSING SHIP

16. When dressing ship* for holidays and other gala occasions, excellent use can be made of the flags of the international

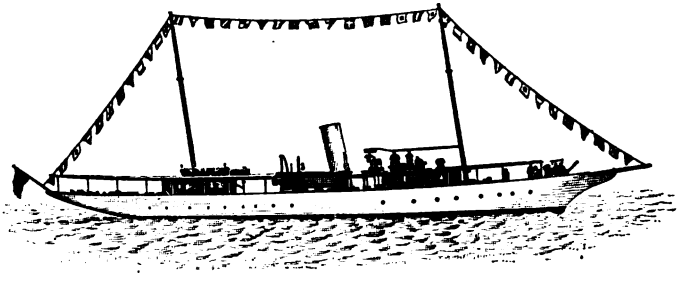


FIG. 5

code. But when utilizing the code flags for such purpose, discrimination and taste must prevail. The flags should be arranged by alternating pennants, burgees, and rectangular flags, and by a uniform and harmonious blending of colors. The ensign should be hoisted at the peak, or flagstaff, at the

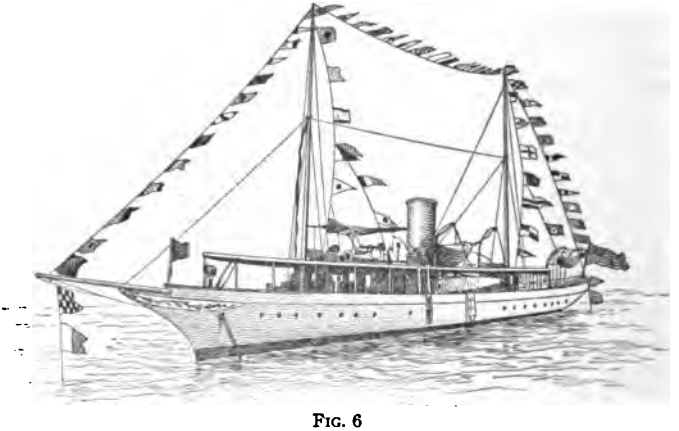


FIG. 6

stern, while the union jack should be displayed on the staff at the bow. According to prevailing etiquette among the large

*In nautical language the term *dress ship* refers to the display of national colors, signals, and other flags, along lines stretched from bow to masthead and stern.

and prominent yacht clubs, no flag officers' flags and burgees must be used in dressing ship nor should the ensign of any

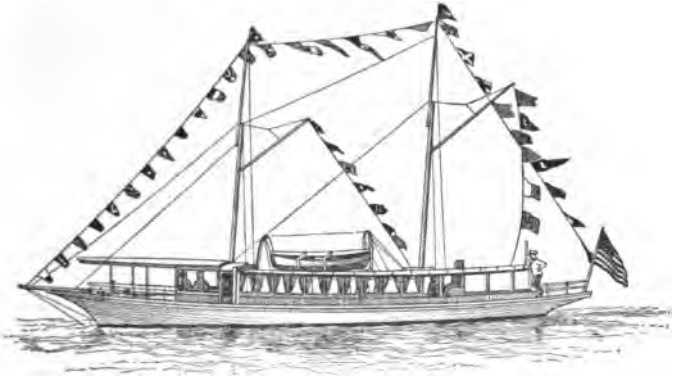


FIG. 7

foreign nation be displayed except where the dressing is in compliment to such a nation, in which case the foreign ensign should be hoisted at the foretop. When dressing ship, the flags should be strung and ready to hoist in position at 8 A. M., but they must not be hoisted before; they should remain hoisted until sunset.

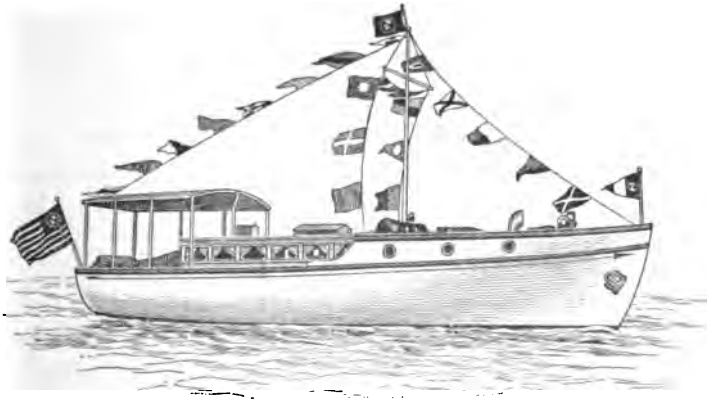


FIG. 8

17. In Figs. 5, 6, 7, and 8 are shown yachts dressed for holiday occasions. The proper way to dress a two-masted

yacht is to string the flags between the mast tops and down to the extreme fore and to the stern of the yacht, as shown in Fig. 5. The additional strings of flags running from each top that are shown in Fig. 6, are not considered conventional. Nor is it good form to fly strings of flags from the two peaks, as in Fig. 7, in addition to those overhead. For a motor yacht with but one signal mast, as in Fig. 8, flags arranged as shown from bow to top and stern and with strings from each spreader is proper.

18. Special Flags and Pennants.—As a general rule, the character of a yacht and of her owner are judged by the flags it flies. When a visiting yacht enters the anchorage of a club, or a rendezvous, she is immediately judged by the colors displayed; therefore, it is important that the impression made should not be a poor one on account of flags being flown in a haphazard and erroneous manner. The table given in Fig. 9 will serve as a guide to the correct way of displaying flags and bunting and the proper time to fly them. The text and arrangement of this table is reproduced by the courtesy of *Motor Boating*, one of the standard periodicals devoted to motor craft; but to the original table has been added the various flags, in colors, that are commonly used by yachts. By consulting this table, uncertainty in the matter of proper colors and when to fly them is obviated.

RULES PERTAINING TO FLAG SALUTES

19. The following rules relating to the use of colors in salutes are adopted generally by most of the well-organized yacht-clubs and motor-boat clubs throughout the country. They will be found of interest to motor-craft operators in general:

Senior Officer.—The senior officer in command of a yacht club anchorage should give the time for colors, make and return salutes, visits, etc. His yacht should remain the station vessel until a senior to him in rank arrives and assumes the command of the anchorage.

The senior officer, when leaving the anchorage, except temporarily, should indicate the transfer of command to the next

in rank by firing a gun on getting under way. All other yachts should salute the officer in command.

Official Day.—The official day on board of a yacht begins with colors (8 A. M.) and ends with the boom of senior officer's gun, at sunset, when the night pennant should be hoisted.

When making colors, salutes, etc., the yacht should always represent the rank of the owner, whether he is on board or not.

When entering or leaving port before colors in the morning, or after colors at sunset, the ensign and distinguishing flags should be shown, and then hauled down on coming to anchor.

Half-Masting.—On Memorial Day and occasions of national mourning, only the ensign should be half-masted. In case of death of the owner of the yacht, the club flag and his private signal should be half-masted, but not the ensign.

When mourning is ordered for death of a club member, only the club flag should be half-masted.

Flags should be mastheaded, both before half-masting them and before hauling them down. Saluting with the ensign should be done by mastheading it first.

Officers Salutes.—The commodore, on entering port to join the squadron, should be saluted, on coming to anchor, by the yachts present. On all other occasions, the commodore should be saluted, on coming to anchor, by the officer in command.

Junior flag officers should be saluted, on coming to anchor, by the officer in command, unless the latter is a senior in rank, in which case they should salute him.

Captains should on all occasions salute the officer in command.

All visits should be made according to rank.

Yachts, passing one another, should always exchange salutes by dipping the ensign once, juniors saluting first. Steam whistles should never be used to make salutes.

The salute to yachts entering port, entitled to a salute, should be made by dipping the ensign once, or by firing a gun, when they let go anchor.

An official salute to a foreign club should be made by firing a gun, with the flag of the foreign club at the fore on schooners and steamers, and at the main on single-masted vessels; or, in the absence of such flag, by half-masting the club flag and

firing a gun. When the salute has been returned, or a reasonable time for its return allowed, the flag should be hauled down, and the club flag hoisted again.

The salute from or to yachts arriving after sunset, or on Sunday, should be made immediately after colors on the following morning.

Flag officers should always fly their pennants, while in commission.

Single-masted vessels should fly the private signal of the owner when under way, and when at anchor the club flag.

Flag Salutes.—When squadrons of different clubs meet at sea, salutes should be exchanged by the commanding officers only.

Salutes from single yachts at sea should be answered by the flag ship only.

Yachts should always salute vessels of the United States navy by dipping the ensign at once.

A yacht, acting as judges' boat, should not be saluted during a race.

A yacht, on withdrawing from any race, should at once lower its racing colors, and allow yachts still competing right of way.

Special Flags.—A yellow flag flown by a yacht will signify that the vessel has contagious disease on board, is quarantined and must not be boarded.

The church pennant is the only flag displayed above the national ensign and then only during divine service when yacht is at anchor.

NOTE—After flags and signals are taken down and not in use they should be folded up neatly and placed in the flag racket. This racket should be provided with a pigeon hole for every flag and signal carried by the yacht; and the name or letter of each flag should be marked above the proper pigeon hole. Such an arrangement will be found very handy and convenient

Before flags are folded up and stowed away they must be thoroughly dry if exposed to rain during the day. Bunting is easily affected by mold, which soon impairs the color of the flags.

GOVERNMENT REGULATIONS FOR MOTOR BOATS

RULES AND THEIR INTERPRETATION

20. Definition and Classification.—The term motor boat used in the following rules includes every vessel, propelled by machinery, whose length does not exceed 65 feet. It does not include tugboats or towboats propelled by steam. The length of the boat is measured from end to end over the deck, excluding sheer.

Motor boats subject to the provisions of the Act approved June 9, 1910, having for its purpose the prevention of collision and regulation of the equipment of such craft, are divided into the following classes: Class 1, boats less than 26 feet in length; class 2, boats 26 feet or over and less than 45 in length; class 3, boats 40 feet or over and not more than 65 feet in length.

21. Lights Carried by Motor Boats.—During all sorts of weather, motor boats must carry the following lights from sunset to sunrise and during this time no other lights that may be mistaken for the regular night signals prescribed shall be exhibited. These rules are embodied in Section 3 of the Act referred to.

(*a*) Every motor boat of class 1 shall carry the following lights:

First.—A white light aft to show all around the horizon.

Second.—A combined lantern in the fore part of the vessel and lower than the white light aft showing green to starboard and red to port, so fixed as to throw the light from right ahead to two points abaft the beam on their respective sides.

(*b*) Every motor boat of classes 2 and 3 shall carry the following lights:

First.—A bright white light in the fore part of the vessel as near the stem as practicable, so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the

light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side. The glass or lens shall be of not less than the following dimensions: Class 2, 19 square inches; class 3, 31 square inches.

Second.—A white light aft to show all around the horizon.

Third.—On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side. On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side. The glasses or lenses in the said side lights shall be of not less than the following dimensions on motor boats of: Class 2, 16 square inches; class 3, 25 square inches.

On and after July 1, 1911, all glasses or lenses prescribed by paragraph (*b*) of section 3 shall be fresnel or fluted. The said lights shall be fitted with inboard screens of sufficient height and so set as to prevent these lights from being seen across the bow and shall be of not less than the following dimensions on motor boats of: Class 2, 18 inches long; class 3, 24 inches long.

Provided, That motor boats as defined in this Act, when propelled by sail and machinery or under sail alone, shall carry the colored lights suitably screened but not the white lights prescribed by this section.

22. Sound Signals for Motor Boats.—The portion of the Act that refers to sound signals reads as follows:

Every motor boat under the provisions of Sec. 4 of this Act shall be provided with a whistle or other sound-producing mechanical appliance capable of producing a blast of 2 seconds or more in duration, and in the case of such boats so provided a blast of at least 2 seconds shall be deemed a prolonged blast within the meaning of the law.

(*b*) Every motor boat of class 2 or 3 shall carry an efficient fog horn.

(*c*) Every motor boat of class 2 or 3 shall be provided with an efficient bell, which shall be not less than 8 inches across the mouth, on board of vessels of class three.

23. Life-Saving and Fire-Extinguishing Equipment of Motor Boats.—Section 5 states that

Every motor boat subject to any of the provisions of this Act, and also all vessels propelled by machinery other than by steam, more than 65 feet in length, shall carry either life preservers, or life belts, or buoyant cushions, or ring buoys or other device, to be prescribed by the Secretary of Commerce, sufficient to sustain afloat every person on board and so placed as to be readily accessible. All motor boats carrying passengers for hire shall carry one life preserver of the sort prescribed by the

regulations of the board of supervising inspectors for every passenger carried, and no such boat while so carrying passengers for hire shall be operated or navigated except in charge of a person duly licensed for such service by the local board of inspectors. No examination shall be required as the condition of obtaining such a license, and any such license shall be revoked or suspended by the local board of inspectors for misconduct, gross negligence, recklessness in navigation, intemperance, or violation of law on the part of the holder, and if revoked, the person holding such license shall be incapable of obtaining another such license for one year from the date of revocation: *Provided*, That motor boats shall not be required to carry licensed officers except as required in this Act.

Section 6 of the same Act provides that every motor boat and also every vessel propelled by machinery other than by steam, more than 65 feet in length, shall carry ready for immediate use, the means of promptly and effectually extinguishing burning gasoline.

24. In Table I is given the equipment required by the law just quoted for the respective classes of motor boats.

25. Running Lights.—It will be noticed that the lights provided for in section 3 of this table are running lights for motor boats in lieu of the regulation lights prescribed for larger vessels; they do not conflict with anchor lights and lights carried by pilot and fishing vessels.

The anchor light for motor boats on inland waters is the same as for larger vessels. On small motor boats it must be placed high enough to be clear of awnings and other obstructions.

26. If a motor boat, through temporary disablement of the machinery or lack of gasoline, finds it necessary to proceed under sail, the white lights should be extinguished and she should proceed with her colored lights only. The law does not specify the size of lights to be carried on motor boats of class 1, but it is suggested by the inspectors that the illuminated portion of such lights or lenses should be not less than 3 inches in diameter.

27. Whistle Signals.—No size or style of whistle, fog horn, or bell (except the bell for class 3) is prescribed, provided

TABLE I

MOTOR-BOAT EQUIPMENT REQUIRED BY LAW

Class of Boat	Boats Carrying Passengers for Hire				Boats Not Carrying Passengers for Hire			
	Sec. 3	Sec. 4	Sec. 5	Sec. 6	Sec. 3	Sec. 4	Sec. 5	Sec. 6
1	Combination light forward. White light aft	Whistle	Life preservers. Licensed operator	Means for extinguishing burning gasoline	Combination light forward. White light aft	Whistle	Life preservers or life-saving devices prescribed by Act	Means for extinguishing burning gasoline
2	White lights forward and aft and colored side lights	Whistle, bell, and horn	Same as class 1	Same as class 1	White lights forward and aft and colored side lights	Whistle, bell, and fog horn	Same as class 1	Same as class 1
3	Same as Class 2	Same as class 2	Same as class 1	Same as class 1	Same as class 2	Same as class 2	Same as class 1	Same as class 1

it is available and sufficient for the use for which it is intended. A mouth whistle capable of producing a blast of 2 seconds or more in duration which can be heard for at least ½ mile has been held to be in compliance with the law. Fog horns cannot take the place of whistles on motor boats of classes 2 and 3.

28. Life Preservers. — Every motor boat not carrying passengers for hire must have life preservers or life belts or buoyant cushions or ring buoys or other device, approved by the Secretary of Commerce, sufficient to sustain afloat every person on board. This includes members of the crew, passengers, children, and babies.

Life preservers or buoyant cushions stuffed or filled with granulated cork or other loose granulated material are not allowed; nor are pneumatic life preservers and cushions permitted. Wooden life floats may

be used as substitutes, provided their dimensions are not less than 4 feet in length, 14 inches wide, and 2 inches thick, and made of well-seasoned white pine or any other wood not exceeding white pine in weight per cubic feet.

Motor boats carrying passengers for hire shall carry one life preserver of the sort prescribed by the Board of Supervising Inspectors for every passenger carried, and the person in charge must be duly licensed.

Motor boats hired as launch liveries are construed as carrying passengers for hire.

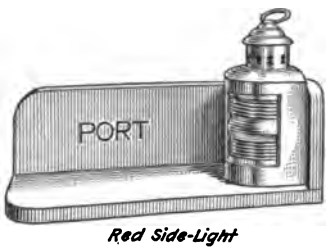
29. Fire-Extinguishers.—No specific means of promptly and effectually extinguishing burning gasoline are prescribed. Besides the usual extinguishers and suitable chemicals, salt or sand in sufficient quantities will serve the purpose. The salt or sand (preferably the two mixed) should be kept in a pail or receptacle ready for immediate use and may be marked *use only in case of fire.*

30. Government Requirements Briefly Stated.—For class 1 or motor boats under 26 feet long, combination red-and-green side light lantern—or bow and colored side light—and stern light must be used; also a whistle or horn capable of producing a prolonged blast for at least 2 seconds.

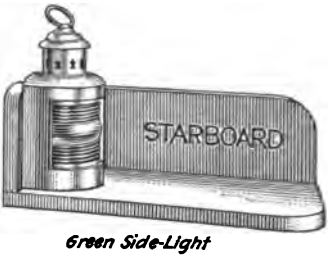
For class 2, or motor boats between 26 and 40 feet long, masthead light (with lens at least 19 square inches), white stern light; red and green side lights (lens at least 16 square inches), and screen boards not less than 18 inches long must be used. The whistle is the same as class 1, with fog horn and bell.

For class 3, or motor boats between 40 and 65 feet long, a masthead light with lens at least 31 square inches, white stern light, red and green side lights with lenses at least 25 square inches, and screen boards at least 24 inches long must be used. The whistle and fog horn are the same as in class 2, with a bell of at least 8 inches across the mouth.

All classes of boats must carry life preservers, life belts, buoyant cushions, ring buoys, or similar approved devices in sufficient number for every person on board, and placed so as to be readily accessible. Life preservers or buoyant cushions must



Red Side-Light

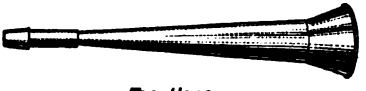


Green Side-Light

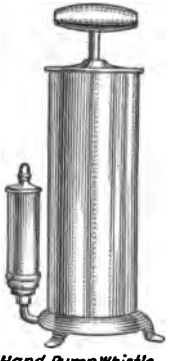
Masthead Light

Fog Bell

Stern Light

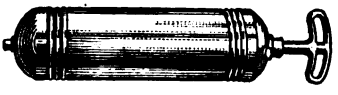


Fog Horn

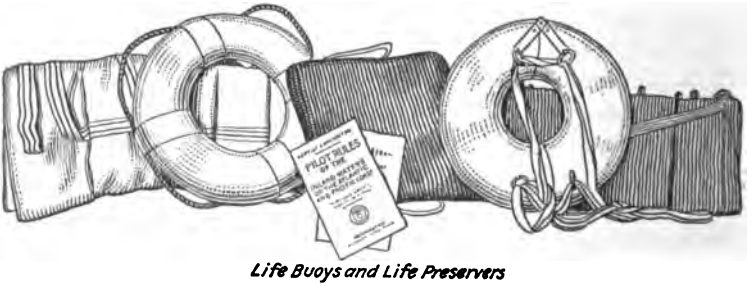


Hand Pump Whistle

Pail with Salt and Sand mixed



Liquid Fire Extinguisher



Life Buoys and Life Preservers

FIG. 10

be capable of keeping afloat for 24 hours a weight exerting a direct downward pull of 20 pounds, on boats not carrying passengers for hire. No pneumatic life-saving appliances or appliances filled with granulated cork are permitted. Planks, gratings, etc., or small boats in tow cannot be substituted for required life saving appliances. Floats of seasoned wood, not exceeding white pine in weight and measuring at least 4 feet by 14 inches by 2 inches, may be used. A fire-extinguisher capable of extinguishing gasoline fires.

All classes of boats when at anchor, must display a white light only, not less than 20 feet above hull, visible around horizon for at least 1 mile.

Two copies of the pilot rules must be carried on board.

31. In Fig. 10 are shown the different articles of equipment required by the government on class 3 of motor boats. As there are several grades and makes on the market, the articles shown are, of course, typical only, but will serve as a useful reminder to operators of that class of boats. The combination red-and-green lantern for class 1 is not shown in this illustration, but it may be procured from any dealer in motor boat supplies.

32. Registration of Motor Boats.—According to law, all motor boats of over 5 net tons engaged in trade must be registered; that is to say, licensed by the collectors of customs. Vessels under 5 net tons are not registered in any case. The license of the vessel obtained from the Custom House (designated a document) is additional to and must not be confounded with the license required for the operator of a motor boat.

Registered vessels must have name and home port painted or otherwise displayed on the stern and the name must be conspicuously shown on each side of the bow.

Although not stipulated by law, boats not registered should have their names conspicuously displayed.

33. Inspection of Motor Boats.—In lieu of the inspection of steam vessels now provided by law, it is required that the design of the engine, boiler, or other operating machinery

of motor boats more than 40 feet in length and not more than 65 feet in length propelled by machinery driven by steam, shall be approved by the local inspectors. Motor boats of 15 tons or over carrying freight or passengers for hire, but not engaged in fishing as a regular business, are subject to inspection whether under or over 65 feet in length.

All motor boats must have on board two copies of the Pilot Rules and Regulations. Copies of these publications are furnished free of charge on application to the local inspectors.

OPERATOR'S LICENSE

34. Licensed Operators for Motor Boats.—The only officer required to be carried on motor boats is the licensed operator provided for in section 5 of the Act of June 9, 1910. This section provides that all motor boats carrying passengers for hire shall be operated and navigated only by a person duly licensed for such service by the local board of inspectors.

35. License Examinations.—In order to qualify for the examination required to obtain a license as gasoline engineer and pilot the applicant should be prepared to answer questions similar to those that follow. The local inspectors before whom the examination is held do not always ask the same questions but the general trend of examination is the same. The subjects involved in these questions have been fully treated in the previous text and should therefore be readily answered by the applicant.

1. What is the first thing to do on taking charge of a gasoline engine?
2. (*a*) How is the gasoline introduced to the cylinder? (*b*) How is it ignited? (*c*) How is it expelled?
3. Give the various systems of generating and igniting gasoline.
4. Explain the difference between a two-cycle and a four-cycle motor.
5. Describe the construction and ingredients of galvanic batteries with which you are familiar.
6. Explain how to wire cells in multiple and in series.
7. Describe how an engine should be started, stopped, and reversed.
8. Explain the functions of the piston.
9. Explain the construction and purpose of a simple switch and describe how it is connected to the batteries.

10. What is the purpose of a spark coil between batteries and motor?

11. What action should be taken in case of failure of the spark plug to work properly?

12. What action should be taken: (*a*) in case of pump failing to work? (*b*) in case it is entirely out of order?

13. What is a fair gasoline consumption per horsepower per hour?

14. How many gallons of gasoline will a rectangular tank hold, which measures 48 in. × 24 in. × 24 in.?

15. What is the capacity, in gallons, of a cylindrical gasoline tank 20 inches in diameter and 2 feet 6 inches long?

16. Explain the object and use of check-valves.

17. How may the engine be prevented from racing in a rough sea?

18. (*a*) How should an engine be keyed up? (*b*) A journal screwed down?

19. What should be done if the gasoline leaked badly?

20. Would air in a gasoline tank and feedpipe affect the proper action of the needle valve? If so, how?

21. How much clearance should there be between the exhaust-guide block and valve-stem nuts? What does this assure?

22. If an engine cannot be started, where is the most likely source of the trouble?

23. (*a*) How and with what should the water pump be repacked? (*b*) The air pump?

24. (*a*) Should gasoline be filtered before being placed in gasoline tank? (*b*) If so, why?

25. (*a*) What grades of gasoline are used? (*b*) Which gives the best results?

26. (*a*) Would it be necessary to stop the engine if one of the valve cap packings blew out? (*b*) Would it lessen the horsepower? (*c*) If so, what percentage approximately?

27. Why is it important to open the throttle valve full way after the gasoline cock has been closed for the purpose of stopping the engine?

28. (*a*) When should the inlet valve close? (*b*) When should the exhaust valve close? (*c*) When should the relief cams close?

29. How is gasoline manufactured?

30. What would be the required mixture of gasoline and air for best results?

31. What is meant by cycle?

32. What is meant by the needle valve?

33. What should be the limit of temperature of gasoline?

34. In a four-cycle engine, give the sequence of operations that take place in the cylinder during two consecutive revolutions of flywheel.

35. (*a*) What is a carbureter? (*b*) What is a vaporizer?

36. In terms of the cylinder, what should be the diameter of: (*a*) the inlet port? (*b*) the exhaust port?

37. Give the engine signals from the pilot house.

38. (*a*) Describe the compass and name its various divisions. (*b*) What is meant by boxing the compass?

39. Name and describe the different kinds of buoys.

40. Describe lights used by all kinds of vessels when under way, and at anchor, signals used in a fog.

41. Name and describe lights on the route for which license is asked giving characteristics of each, also all aids to navigation in the route, and the bearing and distance from one to another.

42. Give number, colors, kind, and location of buoys, beacons, spindles in a particular route.

43. Describe and name all shoals and dangers giving their bearings from prominent objects and the depth of water over them at low and high tide.

44. Give compass bearings and depths of all channels in a route and the distance of the various runs from mark to mark.

45. Plot and find the course and distance from one point to another and plot a series of courses to be run in localities where dangers and shoal water prevent a direct course.

36. License Law for Large Motor Craft.—The present law pertaining to the issuance of license to engineers on motor vessels of 15 tons or more says that

No person shall receive an original license as engineer of vessels of above 15 gross tons, propelled by gas, fluid, naphtha, or electric motors, carrying freight or passengers for hire, who has not served at least 1 year on motor boats, or in the engineer's department of steam vessels, or who has not had at least 2 years' experience in the construction of marine-motor engines and their installation. All examinations for license as engineer of motor vessels shall be reduced to writing and filed with the application of the candidate.

Any person holding a license as engineer of steam vessels, desiring to act as engineer of motor vessels, must appear before a board of local inspectors for examination as to his knowledge of the machinery of such motor vessels, and if found qualified shall be licensed as engineer of motor vessels.

Any person navigating a pleasure yacht of 15 gross tons and under, for pleasure only, holding a master's or pilot's license, is fully authorized to navigate such pleasure yacht in the inland waters of the United States without being required to report to the various boards of inspectors whose district he may be passing through.

37. License for River Motor Craft.—As many vessels navigating rivers are at the present time equipped with gasoline motors, the following rules to obtain license to run them will prove of interest.

Inspectors shall examine applicants for original license as master of steamers navigating rivers exclusively, which examination shall be reduced to writing and made a part of the permanent records of the office of the inspectors making such examination; and no original license shall be issued to any person to act as master of such steamers who has not, by actual service on board of such steamers for a period of not less than 3 years, acquired practical knowledge, skill, and experience essential in case of emergency and disaster, and in the navigation of such steamers with safety to life and property, and at least 1 year of service to have been within the 3 years next preceding the application, and such license shall entitle the holder of the same to act as master on any river steamer of the United States, and no license as master shall be issued to any applicant who cannot read and write, and who has not served at least 1 year as licensed mate or pilot of steam vessels.

38. Licence for River Steamers.—The line of examination to be pursued by inspectors in examining applicants for original license as master of river steamers shall be as follows:

1. As to his general knowledge of the duties of master of such steamers.
2. As to his ability to handle the wheel in case of emergency or disaster.
3. As to the knowledge of his duties and proper method of procedure in case of fire on his vessel.
4. As to his knowledge of proper management of vessel and crew in case of collision and sinking.
5. As to executive ability generally to manage officers and crew.
6. As to his general knowledge and ability to navigate steamers with safety to life and property.
7. As to his knowledge of pilot rules governing the navigation of such steamers.
8. As to his knowledge of signals between the pilot house and engine room.
9. As to his knowledge of signal lights and their proper position on all steam and other vessels.
10. As to duties of master in case of fog or stormy weather, and on such other subjects in connection with the navigation of such vessels as the inspectors conducting such examination may deem proper and necessary.

PILOT RULES

39. The following pilot rules apply to all harbors, rivers, and inland waters of the United States, except the Great Lakes and their connecting and tributary waters, as far east as Montreal, and the Red River of the North and rivers emptying into the Gulf of Mexico and their tributaries. Special rules for

navigating the Great Lakes and rivers whose waters flow into the Gulf of Mexico are issued by the government and can be obtained by application to the Steamboat Inspection Service, Department of Commerce, or from the office of the Local Inspector of Hulls.

In the following rules the words *steam vessel* shall include any vessel propelled by machinery.

A vessel is *under way*, within the meaning of these rules, when she is not at anchor, or made fast to the shore, or ground.

Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

40. Whistle Signals.—The rules relating to signals are as follows:

The whistle *signals* provided in these rules shall be sounded on an efficient whistle or siren sounded by steam or by some substitute for steam.

A *short blast* of the whistle shall mean a blast of about 1 second's duration.

A *prolonged blast* of the whistle shall mean a blast of from 4 to 6 seconds' duration.

One short blast of the whistle signifies intention to direct course to own starboard, except when two steam vessels are approaching each other at right angles or obliquely, when it signifies intention of steam vessel which is to starboard of the other to hold course and speed.

Two short blasts of the whistle signify intention to direct course to own port.

Three short blasts of the whistle shall mean, "My engines are going at full speed astern."

When vessels are in sight of one another a steam vessel under way whose engines are going at full speed astern shall indicate that fact by three short blasts on the whistle.

RULE I.—If, when steam vessels are approaching each other, either vessel fails to understand the course or intention of the other, from any cause, the vessel so in doubt shall immediately signify the same by giving several short and rapid blasts, not less than four, of the steam whistle, the DANGER SIGNAL.

RULE II.—Steam vessels are forbidden to use what has become technically known among pilots as *cross signals*, that is, answering one whistle with two, and answering two whistles with one.

RULE III.—The signals for passing, by the blowing of the whistle, shall be given and answered by pilots, in compliance with these rules, not only when meeting head and head, or nearly so, but at all times, when the steam vessels are in sight of each other, when passing or meeting at a distance

within ½ mile of each other, and whether passing to the starboard or port.

The whistle signals provided in the rules for steam vessels meeting, passing, or overtaking, are never to be used except when steam vessels are in sight of each other, and the course and position of each can be determined in the daytime by a sight of the vessel itself, or by night by seeing its signal lights. In fog, mist, falling snow, or heavy rainstorms when vessels cannot so see each other, fog signals only must be given.

41. Steering Rules.—The steering rules are as follows:

RULE IV.—When steam vessels are approaching each other head and head, that is, end on, or nearly so, it shall be the duty of each to pass on the port side of the other; and either vessel shall give, as a signal of her intention, one short and distinct blast of her whistle, which the other vessel shall answer promptly by a similar blast of her whistle, and thereupon such vessels shall pass on the port side of each other. But if the courses of such vessels are so far on the starboard of each other as not to be considered as meeting head and head, either vessel shall immediately give two short and distinct blasts of her whistle, which the other vessel shall answer promptly by two similar blasts of her whistle, and they shall pass on the starboard side of each other.

The foregoing only applies to cases where vessels are meeting end on or nearly end on, in such a manner as to involve risk of collision; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own, and by night to cases in which each vessel is in such a position as to see both the side lights of the other.

It does not apply by day to cases in which a vessel sees another ahead crossing her own course, or by night to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

42. Navigating Narrow Channels.—When navigating narrow channels the following rule must be observed:

RULE V.—Whenever a steam vessel is nearing a short bend or curve in the channel, where, from the height of the banks or other cause, a steam vessel approaching from the opposite direction cannot be seen for a distance of ½ mile, such steam vessel, when she shall have arrived within ½ mile of such curve or bend, shall give a signal by one long blast of the steam whistle, which signal shall be answered by a similar blast, given by any approaching steam vessel that may be within hearing. Should such signal be so answered by a steam vessel upon the farther side of such bend, then the usual signals for meeting and passing shall immediately be given and answered; but, if the first alarm signal of such vessel be not

answered, she is to consider the channel clear and govern herself accordingly.

When steam vessels are moved from their docks or berths, and other boats are liable to pass from any direction towards them, they shall give the same signal as in the case of vessels meeting at a bend, but immediately after clearing the berths so as to be fully in sight they shall be governed by the steering and sailing rules.

43. Vessels Overtaking.—When one vessel overtakes another, it must be governed by the following rule:

RULE VI.—When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall put her helm to port; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall put her helm to starboard; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.

Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position, with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

As by day, the overtaking vessel cannot always know with certainty whether she is forwards of or abaft this direction from the other vessel she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

44. Vessels Crossing.—The rules governing the crossing of a vessel's path by another vessel are as follows:

RULE VII.—When two steam vessels are approaching each other at right angles or obliquely so as to involve risk of collision, other than when one steam vessel is overtaking another, the steam vessel which has the other on her own port side shall hold her course and speed; and the steam

vessel which has the other on her own starboard side shall keep out of the way of the other by directing her course to starboard so as to cross the stern of the other steam vessel, or, if necessary to do so, slacken her speed or stop or reverse.

If from any cause the conditions covered by this situation are such as to prevent immediate compliance with each other's signals, the misunderstanding or objection shall be at once made apparent by blowing the danger signal, and both steam vessels shall be stopped and backed if necessary, until signals for passing with safety are made and understood.

RULE VIII.—When a steam vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam vessels shall keep out of the way of the sailing vessel.

RULE IX.—Every steam vessel which is directed by these rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other.

RULE X.—In narrow channels every steam vessel shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel.

RULE XI.—In obeying and construing these rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.

45. Sound Signals in Fog.—In fog, mist, falling snow or heavy rainstorms, whether by day or night, signals shall be given as follows:

RULE XII.—A *steam vessel under way, except when towing other vessels or being towed,* shall sound, at intervals of not more than 1 minute, on the whistle or siren, a prolonged blast.

A *steam vessel when towing other vessels* shall sound, at intervals of not more than 1 minute, on the whistle or siren, three blasts in succession, namely, one prolonged blast followed by two short blasts.

A *vessel towed* may give, at intervals of not more than 1 minute, on the fog horn, a signal of three blasts in succession, namely, one prolonged blast followed by two short blasts, and she shall not give any other.

A *vessel when at anchor* shall, at intervals of not more than 1 minute, ring the bell rapidly for about 5 seconds.

46. Speed in Fog.—The rule relating to the speed of a boat in a fog, is as follows:

RULE XIII.—Every steam vessel shall, in a fog, mist, falling snow, or heavy rainstorms, go at a *moderate speed,* having careful regard to the existing circumstances and conditions.

A steam vessel hearing, apparently forwards of her beam, the fog signal of a vessel the position of which is not ascertained shall, as far as the

circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

47. Posting of Pilot Rules.—Provision for the publicity of the pilot rules is made in the following rule:

On steam and other motor vessels of over 100 gross tons, two copies of the placard form of these rules (Form 803) shall be kept posted up in conspicuous places in the vessel, one copy of which shall be kept posted up in the pilot house. On steam and other motor vessels of over 25 gross tons and not over 100 gross tons, two copies of the placard form of the pilot rules shall be kept on board, one copy of which shall be kept posted up in the pilot house. On steam and other motor vessels of 25 gross tons and under, and of more than 10 gross tons, two copies of the placard form of the pilot rules shall be kept on board, and, where practicable, one copy thereof shall be kept conspicuously posted up in the vessel. On steam and other motor vessels of not more than 10 gross tons, two copies of the pamphlet form of the pilot rules shall be kept on board, and, where practicable, one copy thereof shall be kept conspicuously posted up in the vessel.

48. Graphic Illustration of Pilot Rules.—The diagrams shown in Fig. 11 illustrate the working of the pilot rules. The first diagram (*a*) represents two vessels approaching each other head on, the red and green side light of each vessel being visible to both. In this case, the standing rule is that both vessels put their helms to port and pass on the port side of each other, as indicated by the dotted lines, each pilot having previously signified his intention by one blast of the whistle.

In diagram (*b*) is represented a situation of two vessels meeting where the red light only is visible to each, the screens preventing the green lights from being seen. In this case both vessels are passing to port of one another involving no risk of collision. Each pilot, however, should give one blast of the whistle to signify and make known his intention of keeping his course to port.

The third diagram (*c*) represents a situation similar to the one in (*b*) but with the green lights visible to each vessel, indicating that the vessels are passing to starboard of one another. The signal in this case is two blasts on the whistle.

The situations represented in diagrams (*a*), (*b*), and (*c*) and the rules governing the maneuvering of the vessels in each case are easily remembered by memorizing the following stanza:

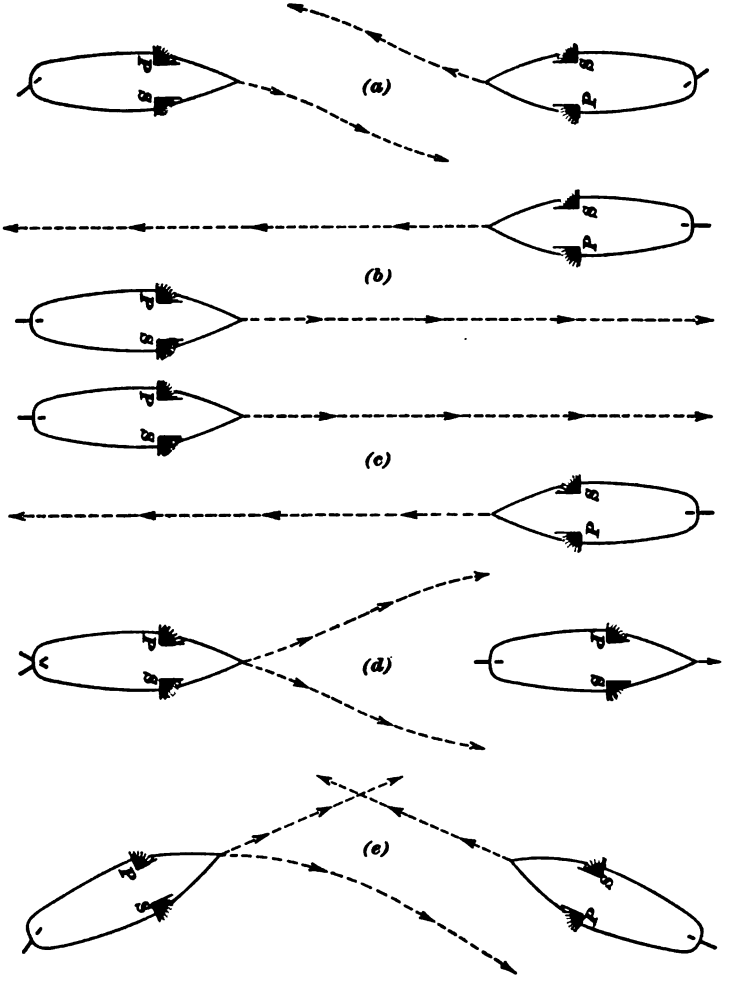


FIG. 11

When both side lights you see ahead,
Port your helm and show your red.
Green to green, or red to red,
Perfect safety, go ahead.

49. In diagram (*d*) is shown a case of one steam vessel overtaking another steam vessel going in the same direction. According to directions prescribed in Rule VI the overtaking vessel may pass on either side of the overtaken vessel ahead, provided the necessary signals for passing have been given with the assent of the overtaken vessel.

In diagram (*e*) is represented a case where two steam vessels are approaching each other at right angles, or, obliquely, in such manner as to involve risk of collision. The law in this case, Rule VII, stipulates that the steam vessel which has the other on her own port side shall hold her course and speed and the other shall keep clear by crossing astern, or if necessary slacken her speed, or stop, or reverse. In diagram (*e*), the vessel on the right having the other on her port side should keep her course and speed while the steam vessel on the left must keep clear of the other by passing astern or stopping. It should be noticed that in any such case of steam vessel crossing, the red light has the right of way. In other words, if a red side-light of a steam vessel (motor craft) is seen on the starboard bow it is necessary to keep clear of it. This case and the rule to be applied is readily committed to memory by the following stanza:

When upon your port is seen
A stranger's starboard light of green,
There's not much for you to do
For green to port keeps clear of you.

50. Rudder and Helm.—In Fig. 11 the vessels in the various diagrams are marked *P* and *S* indicating, respectively port and starboard sides. The heavy line at the stern of each vessel indicates the position of the helm and the rudder, the outboard portion of the line being the rudder and the inboard part the helm. Thus, the expression *port your helm* means that when the helm is to port the rudder is to starboard, as in diagram (*a*), causing the vessel's bow to be swung, or turned, to starboard.

51. Rules Briefly Stated.—The foregoing rules pertaining to the manuevering of vessels meeting or overtaking one another whether by day or night may be summed up in the following brief and concise presentation:

When meeting end on or nearly so, alter course to starboard and pass on port side of other vessel. Follow this rule at night whenever both side lights of another vessel are visible forwards of the beam.

When crossing, the vessel having the other on her starboard side shall keep out of the way of the other.

A power vessel shall keep out of the way of a sailing vessel.

In narrow channels do not overtake and pass another vessel.

In all weathers, except as specified, the following whistle signals shall indicate the courses required herein. When receiving a signal, answer with the same signal.

One blast means: I am directing my course to starboard.

Two blasts mean: I am directing my course to port.

Three blasts mean: My engines are full speed astern.

Never sound a reverse or cross signal. If inadvisable to accept any signal, or if the same is not understood, sound not less than four short and rapid blasts of the whistle. In this case both vessels shall, if required, reduce speed or stop, or reverse, until proper signals are given and understood.

When approaching a bend in a channel sound one long blast.

Give whistle signals only when in sight of signaled vessels by day or night .

In thick weather or fog conditions give fog signals only.

Distress signals, to be given when assistance is required from other vessels or from shore are:

1. In the daytime, a continuous sounding with any fog-signal apparatus, firing a gun, or distance signal consisting of square flag and either above or below it a ball, or anything resembling a ball.

2. At night, flames on the vessel, continuous sounding of any fog-signal apparatus, firing a gun, rockets or shells fired, one at a time, at short intervals.

UNITED STATES BUOYAGE SYSTEM

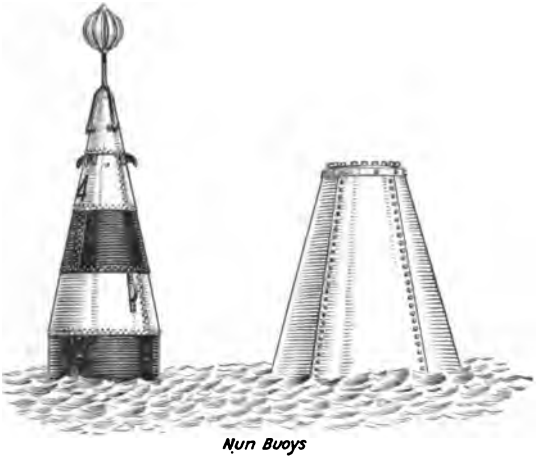
52. When approaching a channel or fairway from seawards, red buoys with even numbers will be found on the starboard side of the channel, and must be kept to starboard when passing in. Black buoys with odd numbers will be found on the port side of the channel, and must be kept to port when passing in.

Buoys painted with red and black horizontal stripes indicate

obstructions, with channel ways on either side of them, and may be passed on either side when entering.

Buoys painted with white and black perpendicular stripes are placed in the deepest part of the channel and should therefore be passed close by.

53. Other distinguishing marks on buoys may be used to mark particular spots; a description of these is given in the printed list of buoys issued by the United States Light-



Nun Buoys

FIG. 12

house Board. Perches, with balls, cages, etc., when placed on buoys, signify turning points in the channel, the color and number indicating on which side they shall be passed.

Different channels in the same bay, sound, river, or harbor are marked, as far as practicable, by different types of buoys. Principal channels are marked by nun buoys; secondary channels by can buoys; and minor channels by spar buoys. When there is but one channel, nun buoys, properly colored and numbered, are usually placed on the starboard side, and can buoys on the port side. Day beacons, stakes, and spindles (except such as are on the sides of channels, which will be colored like buoys) are constructed and distinguished with special reference to each locality, and particularly in regard to the background upon which they are projected.

Wherever practicable, the towers, beacons, buoys, spindles, and all other aids to navigation, are arranged in the buoy list of the Lighthouse Board in the order in which they are passed by vessels entering from seawards. The buoys in thor-

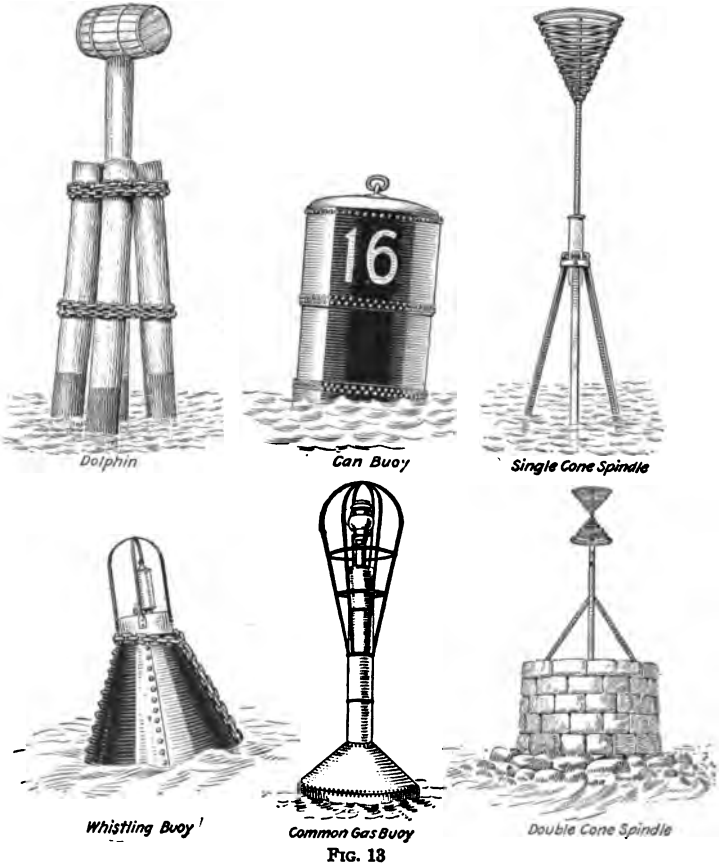


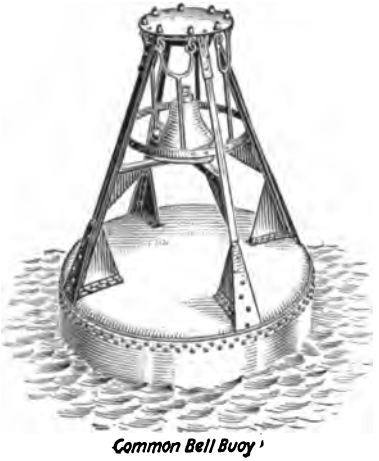
FIG. 13

oughfares and passages between the islands along the coast of Maine are numbered and colored for entering from eastwards.

Vessels approaching or passing lightships in thick foggy weather will be warned of their proximity by the alternate ringing of a bell and the sounding of a foghorn on board the lightship at intervals not exceeding 5 minutes.

54. Types of Buoys.—Floating buoys vary in character and construction according to their purpose or the distance at which they should be seen. The simpler forms are the wooden and iron spar buoys and iron can and nun buoys. For warning in foggy weather, buoys are sometimes fitted with bells, whistles and submarine bells, all actuated by the motion of the sea.

Some important buoys are lighted, usually by means of oil gas compressed in the buoy itself or by acetylene gas compressed in tanks placed in the buoy or generated in it. The light is often flashing or oscillating, for the purpose both of



Common Bell Buoy

FIG. 14

Combination Gas and Bell Buoy

FIG. 15

providing a distinction mark and of prolonging the supply of gas. The use of gas buoys has greatly increased in recent years there being at present more than 346 in the United States. They are very valuable as aids to navigation and often obviate the necessity of establishing expensive light vessels or range lights on shore. Sometimes such a buoy can be placed at small cost where the construction and building of a solid structure would require a vast sum of money. Some of the different types of buoys are shown in Figs. 12, 13, 14, and 15.

55. Buoys are painted and numbered to indicate their position and the side on which they should be passed as already described. Sometimes, buoys may be damaged or sunk or dragged or broken from their moorings by vessels, tows, wreckage, or ice. To keep buoys in order and in their proper position is the principal functions of the lighthouse tenders maintained by the government.

Motor-boat operators should bear in mind that to use a buoy beacon or floating aid to navigation for mooring purposes with boat or raft of any kind is punishable in most states by heavy fines or by fines and imprisonment; except when used in lifesaving. To remove, damage, or destroy any beacon or buoy is punishable by greater penalties.

WEATHER INDICATIONS

56. Wind and weather conditions are by no means the least important matters to motor-boat navigators. A day's trip is often marred by bad weather that might have been foreseen or anticipated with reasonable certainty had attention been given to indications that seldom go wrong. It is true that professional weather forcasters do sometimes make mistakes in foretelling weather but, as a rule, they do not go far astray and on an average 85 per cent. of their predictions are successful.

By availing himself of imformation sent out by the Weather Bureau and making a close and critical observation of local atmospheric conditions, the motor-boat operator may know what weather may be expected within the next 24 hours. To do this he must first study the weather forecasts, which are published in almost every daily local newspaper, and, second, learn how to use the barometer and observe prevailing aspects of weather and sky.

57. Weather Bureau Forecasts.—The Weather Bureau forecasts are based on simultaneous observations of local weather conditions taken daily at 8 A. M. and 8 P. M., 75th meridian time, at about two hundred regular observing stations

scattered throughout the United States and the West Indies. Each of these stations is operated by one or more trained observers, and is equipped with mercurial barometers, thermometers, wind vanes, rain and snow gauges, and anemometers; while many of them also have sunshine recorders, barographs, thermographs, and other devices that register automatically a continuous record of the local weather conditions and changes as they occur. The results of the twice-daily observations are immediately telegraphed to the central office at Washington, District of Columbia, where they are charted for study and interpretation by experts trained to forecast the weather conditions that may be expected to prevail during the following 36 to 48 hours.

Within 2 hours after the morning observations have been taken, the forecasts are telegraphed from the forecast centers to more than 2,100 principal distributing points whence they are further disseminated by telegraph, telephone, and mail. The forecasts reach nearly 160,000 addresses daily by mail, the greater part being delivered early in the day, and none later, as a rule, than 6 P. M. of the day of issue, and more than a million telephone subscribers, mainly in the rural districts, receive the forecasts by telephone within 1 hour of the time prediction is made.

58. By means of these forecasts, the motor-boat operator gets a fair idea of expected weather conditions whenever he is in a place where such forecasts are available. Should he be out of reach of the daily forecasts, he will have to rely on the indications of his barometer and his own observations of prevailing atmospheric conditions.

59. The **barometer** is an instrument that measures the pressure of the atmosphere. There are two kinds of barometers in general use; namely, the mercurial and the aneroid. On smaller craft, such as motor boats, the latter is the more suitable.

The aneroid barometer shown in Fig. 16, is made in various sizes from that of a large watch up to an 8- or 10-inch face. It consists of a cylindrical chamber with a thin elastic top.

The chamber is partially exhausted of air and hermetically sealed. When the atmospheric pressure increases, the top is pressed inwards; and when it diminishes, the top is pressed outwards by its own elasticity, aided by a spring beneath. These movements of the cover are transmitted and multiplied by a combination of delicate levers that cause an index hand to move either, to the right or to the left, over a graduated scale. These barometers are self-correcting (compensated)

FIG. 16

for variations in temperature. They are portable, and are so very delicate (when carefully made) that they show a difference in atmospheric pressure when transferred from the upper part of a room to the floor. The instruments should be handled with extreme care, as they are easily injured. A good aneroid barometer, costing from $20 to $30, is of great value to the navigator as a "weather glass" if carefully observed, but its readings are not so accurate as those of a good mercurial barometer.

60. Meaning of Barometric Changes.—In order to understand the meaning of changes in the atmospheric pressure, as indicated by changes of the barometer, reference should be made to a weather map, such as is published daily by the United States Weather Bureau. On such a map there will, as a general rule, appear one or more approximately circular areas marked Low, while other areas of a more irregular outline are marked High. The first implies that the reading of the barometer within the area indicated is below the average height; the second, that it is above it. Around the area marked Low are drawn lines, each of which has a number attached. These lines are called *isobars*, and the attached numbers are barometric readings; thus, at all points along any one of these lines the reading of the barometer, at the hour represented by the chart, is the same. The point of lowest barometer, or point of least atmospheric pressure, is known as the *storm center*, inasmuch as it coincides very nearly with the area over which a storm prevails. Furthermore, when going from the center in any direction, it will be noticed that the atmospheric pressure increases between each isobar; in other words, when receding from the center, the barometer will gradually rise, and, conversely, when approaching the center, it will gradually become lower. Now, as a storm is always moving, whenever the barometer shows a tendency to drop below the average height, the navigator will know that an area of low pressure is approaching, and as this area indicates the presence of a storm of more or less intensity he is thus warned of the impending change in weather.

61. From this, the important function of the barometer is realized; namely, that by noting changes in pressure an observer is able to foretell with a fair degree of accuracy any decided change in weather conditions. It is well, however, to bear in mind that the printed words Stormy, Rain, Change, etc., have no significance except as a general conclusion. It is not what the index of the aneroid points to but its fluctuations that must be noted in conjunction with the prevailing conditions of wind and weather.

Thus, a rapid rise indicates unsettled weather while a normal gradual rise means settled weather.

A rise with dry air indicates wind from the northward and if rain has fallen better weather may be expected.

A rise with moist air and low temperature indicates wind and rain from the northward.

A rise with southerly wind indicates fine weather.

A steady barometer with dry and seasonable temperature indicates a continuance of very fine weather.

A rapid fall invariably means stormy weather and if it occurs with westerly winds the approaching storm generally comes from the north.

A fall with a northerly wind indicates bad weather with rain.

A fall with increased moisture and a rising temperature indicates wind and rain from the southward, and a fall during calm and warm weather generally indicates rain or showers.

62. The range of the barometer or the amount of fluctuation in the latitudes of the United States is about 3 inches. The normal pressure in fair weather is about 30.50 inches but it may fall to 28.60 or even 28.00 during or on the approach of a severe storm. In the tropical regions, it may fall as low as 27.00 inches during the passage of a hurricane center.

Sometimes when the barometer has remained steady for a number of days, with fair normal weather, one may ascertain its tendency to rise or fall by lightly tapping the glass cover with the finger nails.

The aneroid is usually provided with a recording index hand, which is set by a nut to coincide with the index hand connected with the metallic chamber. The recording index, of course, remains stationary and thus enables the observer to note any change in pressure since the last observation.

63. Weather Indications by Appearance of Sky.—The following rules about weather are worth remembering:

A red sky at sunset presages fine weather; a red sky in the morning bad weather or much wind, if not rain.

A gray sky in the morning, fine weather. A bright yellow sky at sunset presages wind. A pale yellow, wet. By the

preponderence of red, yellow, or gray tints, the coming weather may be foretold very nearly—indeed, if aided by instruments, almost accurately. A dark, gloomy blue sky indicates wind, but a light, bright-blue sky indicates fine weather.

Soft-looking or delicate clouds foretell fine weather, with moderate or light breezes. Hard-edged, oily-looking clouds, wind. Generally, the softer the clouds look the less wind, although rain may be expected; and the harder, more "greasy," rolled, tufted, or ragged, the stronger the wind will prove.

64. When fair weather has prevailed for some days, the first indications of a change is the appearance in the sky of a large accumulation of what are known as *mackerel scales*, a cloud formation resembling the scales of a fish. This is soon followed by a general cloudiness eventually culminating in wind and rain. The higher and more distant the mackerel clouds appear, the longer and more extensive will the approaching rough weather prove to be.

During bad weather from northeast to southeast, if the wind shifts over north to northwest and west the resulting clear weather will not last long. But if the wind shifts over to south, or in the direction of the hands of a watch, the fair weather that follows will be more permanent.

In the latitudes of the United States bad weather usually sets if from the east and southeast with high wind and rain, followed in many cases by a strong northwest wind with dry clear air. When wet weather sets in from the northeast quadrant, the chances are that it will last for some days, or until the wind shifts toward the south and southwest. Sometimes a storm from the northeast is preceded by a rise of the barometer instead of a fall. This is caused by the lower temperature of the damp air coming from the north the cold air always being heavier than warm air.

65. Weather Bureau Signals.—In order to warn the public of impending and pronounced weather changes, the Weather Bureau has adopted a system of flag signals, which are displayed at the various stations of the Bureau, in advance of the approaching change. These signals are most useful to

the motor-boat operator as a check on his own observation of weather condition. One set of these flags, shown in the lower part of Fig. 17, are known as *temperature and weather signals*, while those in the upper part of the same figure are known as *wind and storm signals*. The former are displayed at all stations and at all times; the latter, only at stations along the seaboard, for the benefit of shipping and marine interests.

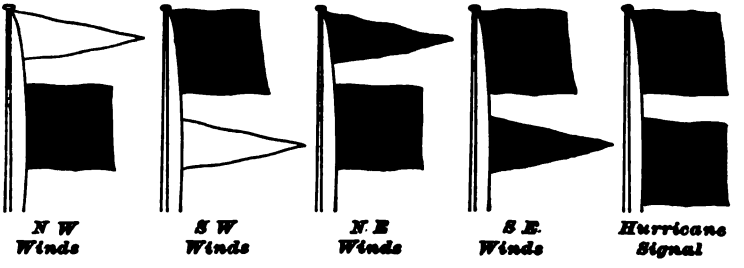
66. Wind and Storm Signals.—The meaning of signals displayed to warn mariners is as follows: A red flag with a black center signifies that a storm of marked violence is expected. The pennants displayed with the flags indicate the direction of the wind; red, easterly (from northeast to south); white, westerly (from southwest to north). The pennant above the flag indicates that the wind is expected to blow from the northerly quadrants; below, from southerly quadrants as shown in the upper part of Fig. 17. By night, a red light indicates easterly winds, and a white light above a red light, westerly winds.

67. Hurricane Warning.—Two red flags with black centers displayed one above the other indicate the expected approach of a tropical hurricane and also one of those extremely severe and dangerous storms that occasionally move across the Great Lakes and the Northern Atlantic Coast. These signals are not displayed at night.

68. Distribution of Storm Warnings.—Storm and hurricane warnings are displayed at nearly three hundred points along the Atlantic, Pacific, and Gulf coasts, and the shores of the Great Lakes, including every port and harbor of any considerable importance. So nearly perfect has this service become that scarcely a storm of marked danger to maritime interests has occurred for years for which ample warnings have not been issued from 12 to 24 hours in advance. The reports from the West Indies are especially valuable in this connection, as they enable the Weather Bureau to forecast with great accuracy the approach of those destructive hurricanes which, during the period from July to October, are liable to sweep the Gulf and Atlantic seaboards.

UNITED STATES WEATHER-BUREAU SIGNALS

Wind and Storm Signals



Flags should be 8 feet square; pennants, 5 feet hoist, 12 feet fly.

Temperature and Weather Signals

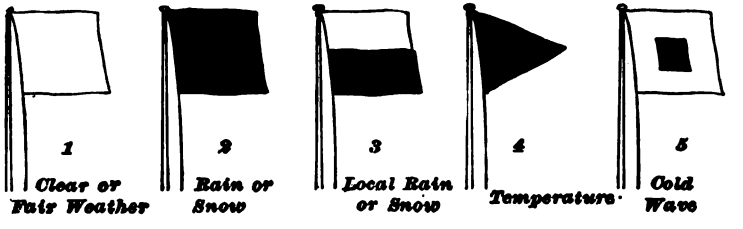


Fig. 17

When No. *4* is placed above Nos. *1*, *2*, *3*, it indicates warmer; when below, colder; when not displayed, the temperature is expected to remain about stationary. No. *5* is used also to indicate anticipated frosts.

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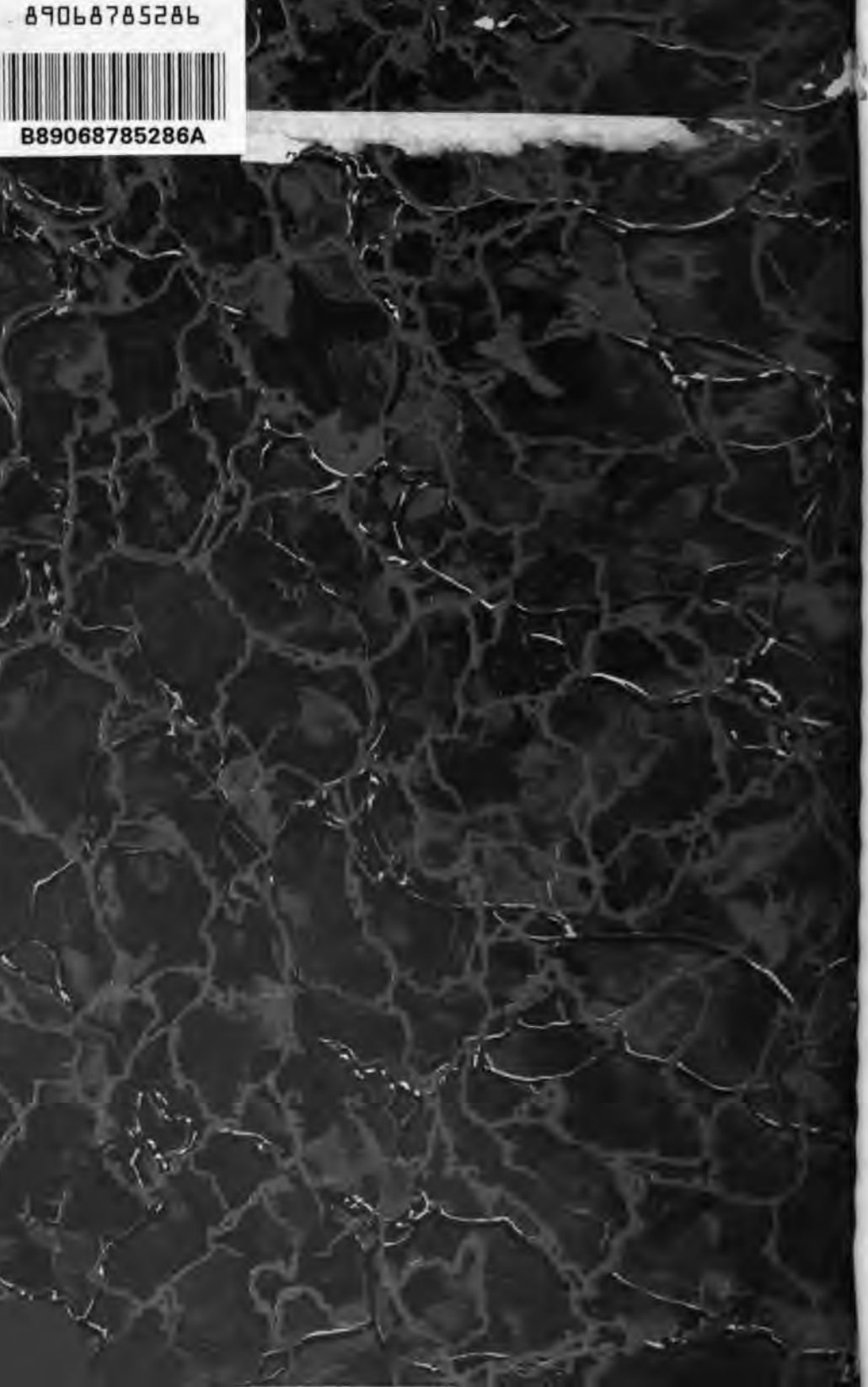

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